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GEORGE ANSEL CARPENTER.

AN APPRECIATION.

For the first time in its history this Association has lost a president during his term of office. Our honored President, George A. Carpenter, who was elected last September, passed away on December 15, 1927. Although apparently in good health when elected, he had not been able to assume the duties of his office.

His life was one of service to his native city of Pawtucket, where he had been city engineer for thirty-six years. Although not college-trained, he was a thorough student and had long been recognized as a capable engineer and a man of sound judgment.

He was a thoughtful engineer, not satisfied with first impressions, who gave to his problems mature deliberation supplemented in a number of cases by original research, such as his studies in the fields of precipitation and run-off.

The demands of his profession for coöperative effort in procuring and disseminating information of value to his contemporaries, led to many committee appointments, in response to which Mr. Carpenter gave conscientious service.

His outstanding characteristics were modesty, quietness, faithfulness, thoroughness — with a personal charm which made him a most likable man.

Mr. Carpenter's long term of public service is one of many illustrations of the fundamental soundness of our municipal government. As compared with the changes in the personnel of engineering departments, dictated by political expediency, which follow each transfer of authority from one political party to another, a term of office such as Mr. Carpenter served stands out in marked contrast; indicating the refreshing groundswell of public opinion, the desire and, finally, the determination, to secure and maintain an honest, efficient administration of community affairs.

Mr. Carpenter was called upon to work with the Water Department of his city to a greater extent than most city engineers, and became well versed in water-works operating problems, as well as in matters of design and construction. This experience was accompanied by increasing activity in water-works affairs, which made him a valued member of our Association and led to his becoming, successively, Director, Vice-President and President.

In his passing, the Association has suffered seriously, and those of us who were privileged to know him have lost a good friend.

HARRISON P. EDDY.

PIPE-LINE WELDING FROM THE OXY-ACETYLENE VIEWPOINT.

BY LE ROY EDWARDS.*

[*Read December 14, 1927 at the Welding Meeting of the Affiliated Technical Societies of Boston.*]

During the last few years there has been a growing demand for a perfectly satisfactory method of joining sections of pipe together, and a great deal of attention by engineers has been given to the solution of this problem.

Among the advantages resulting from oxy-acetylene welding as applied to pipe-line construction are:

Permanence of joint. A welded joint is of the same metal as the pipe and will last as long as the pipe itself without additional maintenance. Strength of welded joints closely approximates the strength of the material in the pipe, and the strength of properly made joints is much greater than that of screwed joints and some other types of construction. The whole line to all intents and purposes becomes practically one length of pipe.

Welded lines facilitate the transfer of liquids and gases because higher pressures can be safely carried and lower friction losses will result, than in screwed or bell and spigot pipes. Welding is very economical, comparing favorably with the cost of screwed joints, and greater freedom from leaks is secured. Should leaks occur the welds can be repaired in place without taking the line apart; this is almost impossible with screwed joints.

The portability of equipment is greatly in favor of welding, as lines can be constructed in any kind of country through which the material can be transported. Welding also has the advantage of using less weight of material than do cast-iron pipe lines. Because of its great tensile strength, welding is largely able to resist the expansion and contraction stresses due to changes in temperature.

Welded steel pipe lines are being used in many instances to replace cast-iron bell and spigot lines, where it would be necessary to use piles or other supports, to carry the weight of the pipe, or allow for conditions of the ground where it is laid, or for vibration and shock. Because of the long lengths of steel pipe available for welded lines, combined with the high tensile strength of the joint, it is generally unnecessary to put in supports, except for elevated sections, as the line after it is welded is sufficiently strong and flexible to stand shock and vibration without injury.

The oxy-acetylene welded joint with complete penetration and with a suitable reinforcement will have strength equal to that of the parent metal in the pipe. There is also an advantage in having a continuous line without obstructions at the joints that will cause friction and create pockets where sediment may collect, as is the case where screwed couplings are used.

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An oxy-acetylene welded line is sufficiently flexible to follow the contours of the ground surface, and it bends easily to a long radius. Welded pipe can also be bent to quite short radii when necessary without injury to welds, and bent pipes that are difficult to assemble with unions or flanges may be joined by welding without any trouble.

The use of special fittings is very costly and usually avoided if possible. In case the fittings are made of cast iron or cast steel it is necessary to have patterns or sweeps made before they can be cast, and weeks may elapse before satisfactory castings are received from the foundry. After that it may take some time for them to be machined for use. The oxy-acetylene welding torch and the cutting torch, in conjunction with a few templets, are all the tools necessary for making almost any type of welded fitting. The work is generally done as the line progresses and the exact pattern of fitting is determined. The fittings made in this way are quickly produced, are much lighter, and, therefore, more easily handled than are cast fittings. (Fig. 1.)

One of the larger gas companies that has been welding pipe for several years, has worked out a very satisfactory plan to meet its ordinary requirements of fittings. Various kinds of fittings have been designed to be welded from steel pipe. Standard dimensions have been adopted for each fitting. The fittings consist of elbows, tees, offsets, reducers, crosses, manifolds, saddles, swage nipples, Dresser caps, and such other fittings as have become standard in their service work. In order to facilitate the making of these fittings the company has constructed cast-iron templets, as shown in Fig. 2. These templets are attached to the pipe by "C" clamps, and the piece to be cut is either marked off with a soapstone pencil and the clamp removed before cutting, or the side of the clamp is used as a guide for the torch in making the cut. The clamps are split on the inside and outside center lines, and before the clamp is removed the center lines are transferred to the pipe section to facilitate assembling the joint. The fittings are made up during slack periods, or days when the weather does not permit outdoor work, thereby keeping a contented welding crew available for all emergencies. Such a system has many points in its favor, the most important of which is that standard-size fittings can be ordered from stock, thereby saving valuable productive time when the pipe line is being laid; the time required to lay out and weld up a fitting in the field may be as great as that needed to weld several lengths of pipe. What the concern laying the pipe is most interested in is the completion of the pipe line in the shortest possible time. Therefore, any work that can be anticipated is of great assistance in completing the pipe line on schedule time.

When fittings are made in the shop, short ends of pipe can be utilized for this purpose, thereby utilizing material that might otherwise be thrown into the junk pile.

There are seasons of the year in the greater part of this country when it is impossible to carry on outdoor construction, and when most companies

FIG. 1.— WELDING AN OFFSET BEND OF 16-INCH PIPE SECTIONS CUT FROM STOCK PIPE.

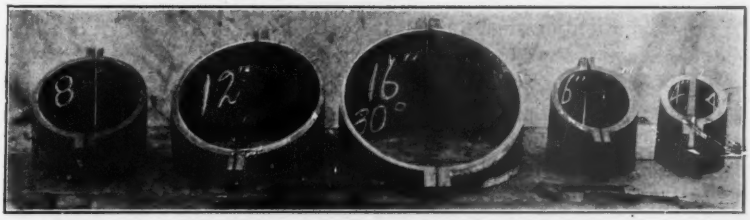


FIG. 2.— CAST-IRON TEMPLETS FOR MARKING-OFF STANDARD PIPE USED IN MAKING UP BENDS AND OTHER FITTINGS.

are obliged to lay off welders they have spent many days or weeks to train in their methods of operation. The idea of making up stock fittings has given steady employment to welders throughout the year; it is a means of keeping down the labor turnover and reduces the cost and need for training new men when the outdoor season opens. There is another point of interest to employers, and that is that seasonal work demands high wages, while steady employment enables employers to hold men at a fair wage.

Saving of time by laying lines by the oxy-acetylene welding process has been found to be greatly in its favor. In lines joined by screwed joints only one section is joined at a time, while in a welded line as many lengths can be joined as there are welders available; this may involve several hundred feet of pipe. In one instance 50 miles of 10-in. pipe were welded and laid through a series of towns in 45 days. The pipe was welded faster than three trenching machines were able to dig when working 24 hours per day. Records like this require a trained organization and competent welders interested in producing the largest number of welds per day.

There are many other reasons aside from those described why the oxy-acetylene welding of pipe lines is desirable. While the process is not at all new to pipe welding — it was started over fifteen years ago — the service rendered by the early oxy-acetylene welded lines has proved the practicability of the process, and it is this very enviable record which furnishes the reason for the tremendous present-day activity along these lines. Oxy-acetylene pipe-line welding has proved practical and economical and at the same time permits speedy construction under all conditions.

Preparation.

In considering the construction of a pipe line it is necessary to organize a personnel to handle the field operations so that a careful check can be made as the work progresses, and so that good workmanship and speedy construction will be insured. In making welded joints dependence must be placed on the skill of each individual welder, and for this reason the welders should be carefully trained and made thoroughly familiar with pipe-line welding.

Special attention should be given the selection of welders. Each man should have impressed upon him the importance of his operations. Before a man is allowed to weld on a pipe line carrying high pressure he should be required to demonstrate his welding skill on one or more test pieces in the form of short pieces of pipe supported about 18 in. above the ground. A complete weld should be made without turning the pipe. The weld should then be cut into strips, about 2 in. wide, and each strip should be tested by placing it in a vise with the edge of the weld even with the top of the jaw of the vise and with the outside of the weld toward the operator. By using a clamp on the upper part of the test piece it should be bent so that the bending strain is localized on the inside of the weld, which ordi-

narily is the weakest part of the joint. A good oxy-acetylene weld can be bent through 180 degrees without failing.

This is a suitable field test but, as a means of determining the value of the welder and his work, does not compare with the tensile tests, that will be described later.

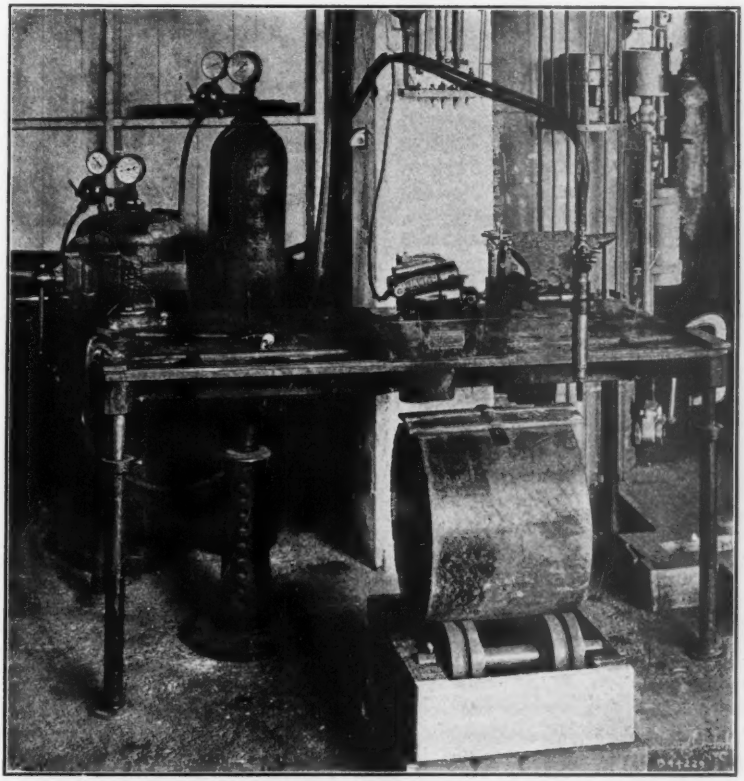


FIG. 3.— CUTTING A LARGE DIAMETER PIPE WELD INTO TEST STRIPS WITH THE RADIAGRAPH.

Particular attention should be given to determine if bottom or overhead welds are as good as those on top. If the work of the welder is satisfactory on one or more tests of this kind it can be considered safe to allow him to weld on a high-pressure pipe line. If his work is not satisfactory but shows promise of ability, he should be put through a course of training until he is able to make good welds. If this procedure is followed, the men will understand that perfect work is expected of them, and they will continually strive to maintain a high standard of quality.

It is customary for concerns or contractors who are doing the highest class of work to have in their employ one or more leading welders who are capable of instructing apprentices, or deciding on the qualifications of new employees. Instruction is carried on until the operator is able to meet the test and make welds of standard quality.

A method of testing welded joints, which has had the approval of engineers and contractors interested in doing the highest grade of welding, is to take a full section out of the line, about 18 in. long, with the weld in the center. This section is then cut into longitudinal strips, about 2

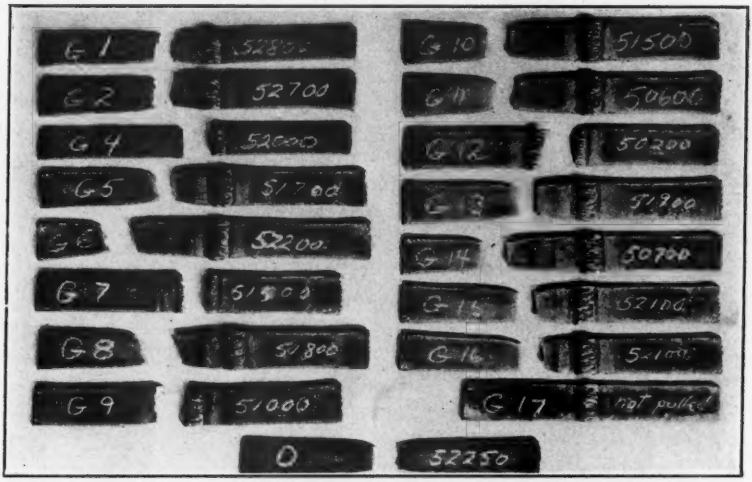


FIG. 4.— TENSILE STRENGTH OF TEST PIECES CUT FROM PIPE WELD.

in. wide, by the use of a radiagraph. This is a motor-driven machine carrying an oxy-acetylene cutting torch. Each strip should be numbered consecutively around the circumference of the entire section. (See Fig. 3.) The strips are then put into a testing machine and pulled to determine the tensile strength of the weld. (Fig. 4.) A sample of the pipe is also procured, cut and tested in the same way for comparison. The results of a specimen test of this kind will give a definite idea of the strength of the welds that are being made and, further, give a figure for the average strength of the entire pipe joint.

Standardization of all torches, regulators and equipment used on the line is very desirable, because it facilitates maintenance, insures uniformity in procedure, and enables all welders to operate under exactly the same conditions. By standardization of equipment, tip sizes, pressures, speed of operation, and methods of welding, the kind of joint produced can be controlled, and the value of standardization is evidenced in more economical and more satisfactory welding.

A high grade of welding-rod should be used, because the strength and uniformity of the weld depend to a very considerable extent on the material that goes into it.

Material.

In some parts of the country the condition of the soil is such as to cause rapid corrosion of steel pipe.

Soil conditions, where the line is to be laid, should be the determining factor as to the desirability of employing soil proofing. The usual method of applying soil proofing is to dip or paint the pipe with a bitumastic coating, and if soil conditions are unusually severe the pipe should be wrapped with burlap, or one of the various grades of roofing paper that offers the best protection for the particular soil condition. When wrapping is resorted to, it is usually done when the bitumastic coating is hot.

After the welds have been made and tested, the exposed portions are wrapped or coated to produce uniform conditions. The ends of the pipe should be chamfered to an angle of about 45 degrees to within $\frac{1}{16}$ in. of the inside edge of the pipe. The nearer the beveling towards the inside edge, the easier it is to get complete penetration, and we all know that pipe in perfect alignment, welded all the way through, is much stronger than pipe welded with partial penetration.

Aligning of Pipe.

Next in importance to the welding operation is the care and attention required in aligning the joints, in order that perfect welds can be produced economically.

There are various methods of aligning pipe, and the method selected depends a great deal upon the conditions where the pipe is to be welded and laid.

Some favor supporting the pipe on timbers and blocking it up so that the edges are in proper position and the pipe can be rolled while making the weld. This method is very satisfactory. Others prefer cutting a "V" in blocks so that the pipe can be revolved without being thrown out of line. In other cases a pedestal block with two rollers is used. This, of course, reduces the friction in turning the pipe. All of these methods are satisfactory and are commonly used on pipes 10 in. in diameter or smaller.

Devices have been developed that are of considerable assistance in holding the pipe in line during the tacking operation. One device consists of a lower member cut out of steel plate bent to the radius of the pipe and extending beyond the end of the pipe to which it is attached. (Fig. 5.) This extension forms a support for the adjacent pipe, while the exposed portions of the joint are welded. This bottom member is quickly adjusted to the pipe by a series of links to which it is attached on one end, while a

cam on the other end engages a curved lip on the bottom member, forming a linkage that provides rapid adjustment.

The handle attached to the cam affords sufficient leverage to draw the links firmly together and raise a heavy pipe into proper alignment.

Another device frequently used is made from a pair of pipe clamps, to each half of which bars have been welded. (Fig. 6.) These bars extend a few inches beyond the side of the clamp, and near the end of each bar, on the upper half of the clamp, holes are drilled and tapped for set screws that are used to attach the clamp firmly in position with the bottom section in close contact with the pipe. The adjoining length of pipe is, therefore, quickly and accurately positioned for welding. It is obvious that any scheme for aligning the joints so that the edges are in proper position will facilitate the welding operation and assist in producing more satisfactory welds.

Methods of Laying Pipe.

Where it is possible to have fairly straight runs, it is advisable to make all possible welds on the surface, either alongside the trench or over the trench, with the pipe supported on timbers. The pipe can then be lowered into the ditch, where it can be welded to the main line by excavating a bell hole and making a tie-in weld. (Fig. 7.) On small pipe lines a tie-in weld may be made on the ground alongside the trench, or while the pipe is supported on timbers over the trench, because the flexibility of the pipe and the strength of the gas-welded joints permit lowering the pipe into the trench progressively. Since a tie-in weld is made more slowly than a weld made by rolling the pipe, it is advisable to use as many of the latter as possible. A tie-in weld is a one-man job, whereas when the pipe is being rotated several men can weld simultaneously on the same section which may consist of many lengths.

Lowering Pipe into Trench.

There are several methods for lowering pipe into the trench. One that has proved quite satisfactory in the case of heavy lines is as follows: Portable steel horses to which are suspended chain blocks and slings are placed in position after the completed section of welded pipe line has been placed over the trench, supported on timbers, and made ready for lowering. The slings are then attached to the pipe line, and the chain blocks are used to lower it into the trench. (Fig. 8.)

Another method uses a lever with a rope sling. (Fig. 9.) The operation is performed by having a supporting horse used as a fulcrum, and a lever to which a rope is attached to the short end. This rope is led around the pipe, and two or three turns are taken around the end of the lever to be used as a snubber. The lever is then used to raise the pipe off the supporting timbers, and as the rope is released the pipe is lowered into the ditch.

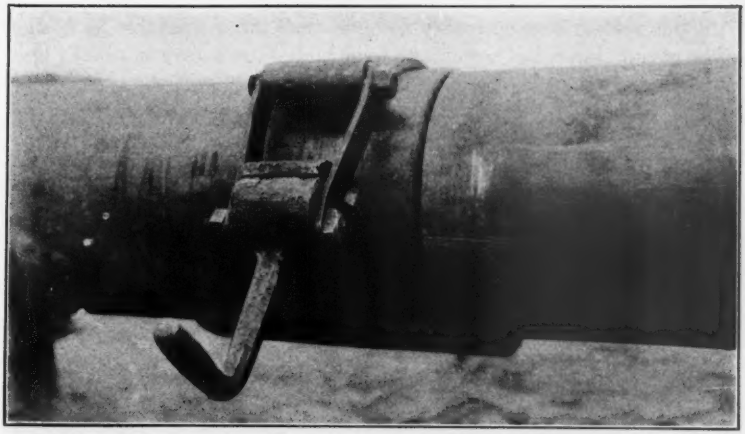


FIG. 5.— DEVICE FOR HOLDING PIPES IN LINE WHILE TACKING.

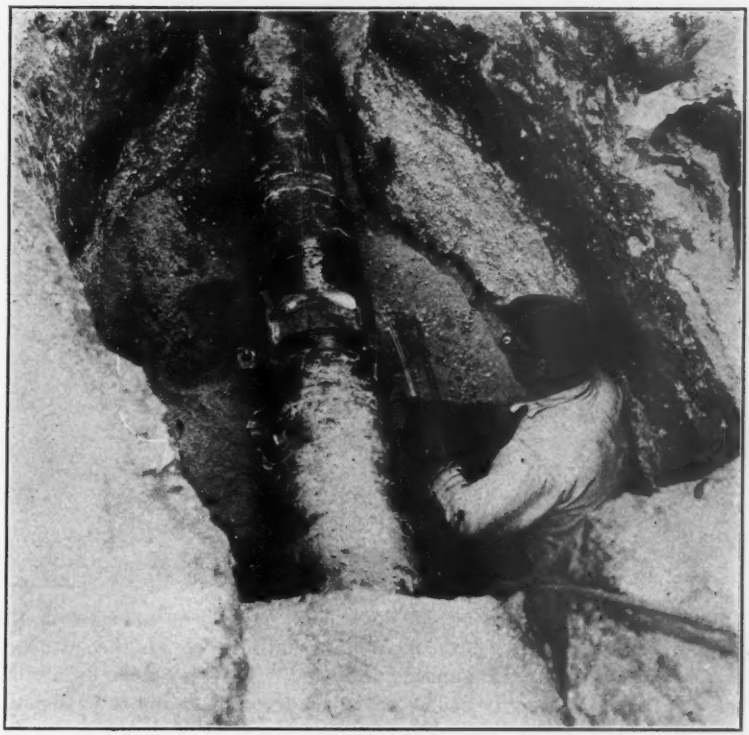


FIG. 6. — ANOTHER DEVICE FOR HOLDING PIPES IN LINE WHILE TACKING.

With this system it is necessary to have more labor available for a short period of time, but it has been found to be quite satisfactory on smaller lines.

A method that has been successful on heavy lines is the use of heavy timbers supported on the ends and extending over the pipe trench. These

FIG. 7.— MAKING TIE-IN WELDS.

timbers are either turned or the sharp edges have been knocked off the corners to prevent chafing of the rope. The end of the rope is then attached to the timber with two turns and then knotted. The other end is led around the pipe; then three or four turns are taken around the timber so that the strains on each supporting rope are on opposite sides of the timber. The lever is used to raise the pipe off the sleepers which are then withdrawn.

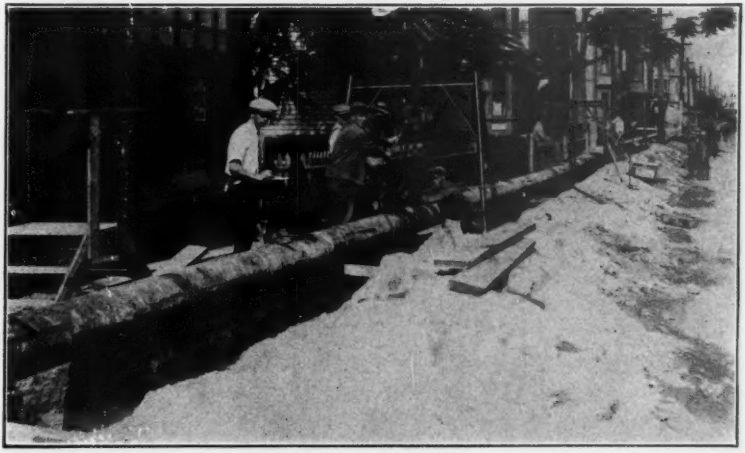


FIG. 8.— LOWERING PIPE LINE INTO TRENCH WITH SLINGS, CHAIN BLOCKS AND OTHER APPARATUS.

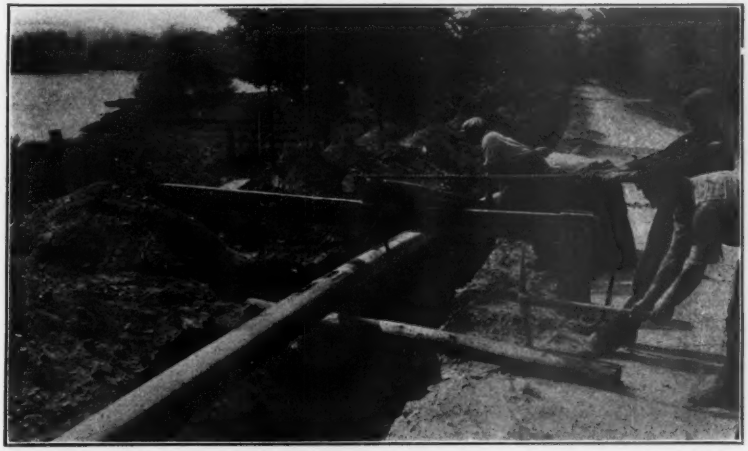


FIG. 9.— ILLUSTRATING USE OF LEVER AND ROPE SLING FOR EASING PIPE LINE INTO TRENCH.

FIG. 10.— SPANISH WINDLASS FOR EASING HEAVY PIPE LINE INTO TRENCH.

FIG. 11.— DRIVING PIPE BIT UNDER HIGHWAY TO TUNNEL FOR PIPE LINE.

FIG. 12.— PIPE LINE THREADED THROUGH PIPE DRIVEN UNDERNEATH ROADWAY.

The pipe is allowed to settle into the supporting rope. The turns around the timber are used as snubbers for lowering the pipe into the ditch. (Fig. 10.)

There is a handicap at times through being obliged to lay a pipe under a street that has been newly paved, and where the authorities will not allow the pavement to be broken. This handicap has been overcome by the use of a bit which has been cut on the ends into saw teeth, the ends of which are protected by welding on tool steel or alloy steel to form a hard cutting-edge. The trench excavation is then made to the edges of the roadway, and the bit is then driven through with some type of battering ram. A pipe duct is then inserted in the opening made, and the welded pipe line is passed through. (Figs. 11 and 12.)

Testing of the Line.

In the laying of pipe lines in populated areas it is generally customary to weld and lay the line as quickly as possible, not only on account of the hazard of having an open trench along the highways but also because the authorities who issue permits for the laying of lines insist that the streets be opened, the line laid and the street closed within a specified time. Sometimes not over twenty-four hours are allowed.

Marking of Welds.

In the welding of pipe lines it is customary to employ a system whereby the work of each welder can be identified at the time of test and until the line is in the trench and ready for covering. This point is sometimes overlooked as being of no great consequence. (Fig. 13.)

There are various methods of marking pipe. Some use a steel stamp, each letter designating a welder; others use a characteristic mark which is made by the welding on of metal next to the joint from the filler rod; others use paint for marking the initials of the welder, next to the joint. This last system of marking is not permanent, and it is sometimes advisable that the mark designating the welder should be a permanent record.

Expansion and Contraction.

Welded pipe lines laid in trenches at a reasonable depth below the surface of the ground are subjected to comparatively small temperature variations, and it is, therefore, ordinarily unnecessary to provide for expansion and contraction as slight curvatures up and down and sideways are usually enough to take care of the slight changes that occur during the various seasons of the year. However, it is necessary at times to use expansion joints, particularly on long, perfectly straight lines, or lines installed to handle steam or hot liquids and gases, or where the lines are exposed to atmos-

FIG. 13.— MARKING PIPE LINE WELDS TO FIX RESPONSIBILITY OF WELDER.

FIG. 14.— TORPEDO HEAD CLOSURE WELDED TO PIPE LINE FOR TESTING.

pheric conditions, as the increased variation in temperatures causes a much greater expansion and contraction for which provisions must be made.

Expansion joints are made in various types, such as long slip joints, which consist of a long section of pipe with a smooth machined surface which is inclosed in a large section of pipe with some form of stuffing-box on the end. This will allow the entire section to move in or out without serious loss of pressure. Another type used quite extensively is a large "U" bend which can be welded into the line at the proper location. Another type is a coil made by bending pipe in a complete circle. This method is only used on small pipe lines where leakage from the ordinary expansion joint could not be tolerated. Where there are valves on pipe lines, expansion joints should be provided for the protection of the valve, especially if the valves are made of cast iron. An expansion joint placed on one side will be sufficient to protect the valve from the strains set up by the expansion of the lines. This is particularly true if the usual valve box is installed.

Methods of Closing Pipe Line for Testing.

Various methods are used to close the ends of completed sections of pipe lines preparatory to applying the required pressure test. One method commonly used where the test pressure is high is to make a torpedo-shaped head which is welded to the end of the pipe line, and after satisfactory test has been made this end is cut off and used again for the next test. (Fig. 14.) Another method is to weld a disc onto the end of a short piece of pipe of the same diameter as the pipe line to be tested, and then to weld this section onto the pipe line, as was done for the torpedo type of head. (Fig. 15.) Instead of welding the heads onto the pipe they can be attached by the use of a Dresser coupling, and fastened to the pipe line by special clamps on the pipe and head that are connected by bolts to prevent the head from being blown off during the test. This type of coupling leaves the end of the pipe in condition to weld without any further preparation. (Fig. 16.) Another type of head is one made from a Dresser coupling in which a disc has been welded to one end of the sleeve and the other end of the sleeve is left open to be slipped over the end of the pipe to be tested. The sleeve is drilled for about 8 $\frac{1}{2}$-in. set screws which, when screwed against the pipe line, prevent the head from blowing off when the pressure is applied. It is evident that neither of the last-mentioned methods is applicable when high pressures are specified.

There are several methods in use for testing the lines; applying hydrostatic pressure with a hammer test is probably the most severe. This is made by pumping water into the line at a specified pressure, being sure to displace all air, and hammering the pipe adjacent to the weld. The impact of the hammer-blows sets up vibrations that travel through the pipe and

FIG. 15.— PIPE LINE CLOSURE MADE WITH FLAT DISC WELDED ON FOR TESTING.

FIG. 16. — PIPE LINE SEALED BY MEANS OF DRESSER COUPLING FOR TESTING.

show up any weak joints. When water is not available and drainage is difficult, this method is not used. In the case of high-pressure water lines, however, this test is very desirable before the lines are turned over for actual service.

The method commonly employed in testing at ordinary pressures is by the use of air pressure and the application of soap and water solution which is painted over the joint; in case of a leak it will indicate itself by the

FIG. 17.— TESTING PIPE LINE WITH PORTABLE AIR COMPRESSOR EQUIPMENT.

air bubbles which form on the outside of the joint. This test is extensively used and has been found to be quite satisfactory. (Fig. 17.)

Several important points to be considered in the construction of gas-welded steel pipe lines have been touched on in order to indicate the need for careful planning so that satisfactory construction can be expeditiously accomplished.

The use of welded steel pipe lines is still in its infancy. However, gas companies, public utilities corporations, power plants, oil and water companies, and others interested in pipe lines that must be tight, and of low installation and maintenance cost, are more and more frequently turning to gas-welded steel pipe lines, as they more effectively meet the requirements of the consumers.

(*For discussion of this and other papers on welding, see p. 42.*)

THERMIT PIPE-WELDING.

BY ROBERT L. BROWNE.*

[*Read December 14, 1927 at the Welding Meeting of the Affiliated Technical Societies of Boston.*]

What is now universally known as the "thermit process" was originally perfected by Dr. Hans Goldschmidt of Essen, Germany, for the reduction of pure metals from their oxides. While there are many thermits, depending upon the metal oxide used, this paper will be confined to iron thermit, which is the variety used for welding purposes, and referred to merely by the term "thermit" for the sake of brevity. Thermit is a mixture of finely divided aluminium and iron oxide.

The fundamental principle of the thermit process is the high chemical affinity of aluminium for oxygen. Stated in simpler terms, it is really aluminium burning with the oxygen of iron oxide sustaining combustion, just as, for instance, paper or wood would burn in air with the oxygen of the atmosphere sustaining combustion. It is more difficult, of course, to start aluminium burning, requiring as it does a temperature of 2 800° F. Once started, however, it continues to burn without further external application of heat. The initial temperature (2 800° F.) is obtained by means of a small quantity of so-called ignition powder, placed in one spot anywhere on top of the thermit in the crucible and ignited with a match.

The aluminium in burning combines with the oxygen of the iron oxide to form aluminium oxide or slag, setting the iron free. The slag, being lighter than the iron, floats on top. The temperature of this reaction is approximately 5 000° F., a temperature which, properly controlled, can be utilized to advantage in many ways for welding purposes.

Briefly, in joining pipe end to end by the thermit process of welding, thermit is used only as a heating agent to bring the pipe ends, which have been previously faced and brought together, up to a welding temperature. They are then forced together by means of a special hand-operated clamping-device of simple design, thus making a forged weld. This is the real important feature of the thermit pipe-weld and the main reason for its merit as a permanent non-leaking union.

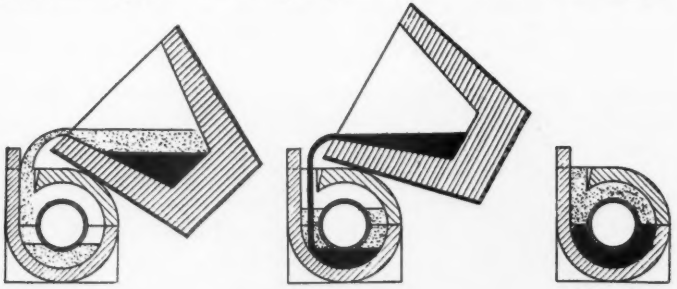
The thermit steel and slag, which are controlled by means of a special two-part cast-iron mold enclosing the joint, are discarded after the weld is completed, thus leaving no foreign material that might be of a more or less porous nature as an integral part of the joint structure.

The thermit process is most commonly used in connection with standard and extra-heavy pipe up to and including 6 in. and with double extra-heavy pipe up to and including 4 in. The rate of production varies

*Metal and Thermit Corporation, Boston, Mass.

from twenty to fifty joints a day, two men working, depending upon the size and weight of pipe and facilities for executing the work.

The actual steps in executing a thermit pipe-weld are as follows: The pipe ends are first faced smoothly and squarely by means of a small hand-operated milling tool. A clamp is placed near the end of each pipe and



THERMIT PIPE-WELDING OPERATION.

FIG. 1.— Slag flowing into mold and coating outside of pipe and inside of mold.
FIG. 2.— Slag in mold and steel following, displacing slag in bottom part.
FIG. 3.— Both slag and steel in mold but steel separated from pipe and mold by film of slag.

the whole is held rigidly together by two draw bolts, diametrically opposite after lining up the pipe, so that the faced ends butt and coincide. A two-part cast-iron mold, parted horizontally through the middle, is next placed, so that it encloses the ends of the pipe to be united. A thermit portion, the weight of which corresponds to the size and weight of pipe, is then reacted in a flat-bottom crucible and poured into the mold through an opening at

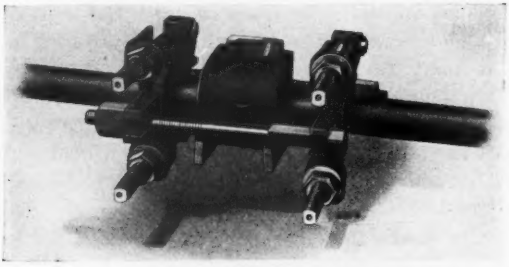


FIG. 4.— MOLD FULLY ASSEMBLED READY FOR WELD.

the top. The intense heat of the thermit steel and slag soon brings the pipe ends up to a welding heat, at which time they are squeezed together by tightening the draw-bolt nuts one complete turn, which is sufficient to assure a 100 per cent. weld. (See Figs. 1–5.)

It will be observed from this description that the personal element enters into the operation only to a slight degree, the whole operation being of a more or less mechanical nature, thereby making the process practically

FIG. 5.— WELDING PIPE LINES WITH THERMIT.
Manhattan State Hospital for the Insane, Ward's Island, N. Y.

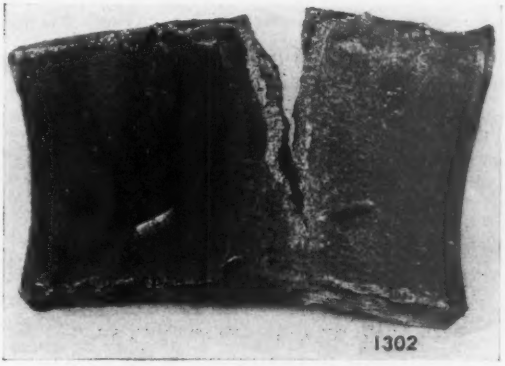


FIG. 6.— THERMIT WELD.
Three-inch extra heavy pipe subjected to breaking test. Note that pipe fractured at some distance from weld. The line of weld is seen at left of fracture.

fool-proof and assuring uniform results. It should also be noted that no outside source of power is required, and that the apparatus is light in weight and therefore easily handled. A pipe joint made in this manner is just as strong in every way as the pipe itself.

Thermit prepared for pipe-welding is packed in individual water-proof bags. Constituting as it does quantity of heat, the weight varies for the different sizes and weights of pipe.

Generally speaking, thermit pipe-welding is peculiarly well adapted for making a high-class pipe joint. Up to the present time it has been most generally used in connection with chemical and refrigerating plants, oil refineries, and for high-pressure steam, hydraulic and compressed-air pipe lines. Figure 6 shows the result obtained by subjecting a 3-in. thermit-welded pipe to a breaking test. The pipe fractured at some distance from the weld. Other pipe tests are tabulated below:

Character of Pipe	Yield Point, (Actual), Lbs.	Ultimate Tensile Strength, (Actual), Lbs.	Approximate Location of Rupture	Bursting Pressure Lbs. per Sq. In.	Approximate Location of Rupture
1-*in. Standard*					
Straight..	18 000	27 900	Between grips	11 580	Center of pipe
Coupling.	17 250	20 320	Root of thread at coupling	9 260	6 in. from coupling
Welded..	16 500	26 130	2½ in. from weld	10 560	4 in. from weld
1-*in. Extra Heavy*					
Straight..	19 200	34 730	Between grips	13 510	2 in. from end of pipe
Coupling.	...	18 770	Root of thread at coupling	13 310	3 in. from end of pipe
Welded..	23 000	34 970	8 in. from weld	14 220	2 in. from end of pipe
1¼-*in. Standard*					
Straight..	22 300	37 670	Between grips	9 440	7 in. from end of pipe
Coupling.	21 380	28 500	Root of thread at coupling	8 050	7 in. from end of pipe
Welded..	20 930	36 020	At weld	8 460	1½ in. from end of pipe
1¼-*in. Extra Heavy*					
Straight..	29 380	50 620	Between grips	12 900	1½ in. from end of pipe
Coupling.	29 100	29 100	Root of thread at coupling	12 770	2 in. from end of pipe
Welded...	27 800	50 980	6 in. from weld	11 490	1 in. from end of pipe

No great importance should be attached to figure for yield point on account of the possible error of observation.

In closing, I wish to repeat and leave with you the following few important features pertaining to welding pipe by the thermit process, which from a strictly engineering standpoint are essential to the production of uniformly strong welds:

1. The weld is forged.

2. The slight degree to which the personal element enters into the operation makes it fool-proof and assures uniformity of results.

3. Facility with which the work can be executed, due to the simplicity of the operation, portability of apparatus and the absence of any need for outside source of power — all of which make for rapid and economical production.

(*For discussion of this and other papers on welding, see p. 42.*)

PIPE WELDING AND OTHER RECENT DEVELOPMENTS IN WELDING.

BY D. H. DEYOE.*

[*Read December 14, 1927 at the Welding Meeting of the Affiliated Technical Societies of Boston.*]

Let me outline first a few of the recent important developments in the welding field.

Atomic-Hydrogen Arc Welding. As regards this process, I simply wish to state my feelings as to the possible applications for its use. I do not feel that in any way will this process supersede metallic-arc welding where metallic-arc welding is now satisfactory, but will broaden its field. It makes possible the welding of thinner metals ranging in thickness from $\frac{1}{16}$ in. to a few mils which cannot be welded satisfactorily with the metallic-arc process, and it will open up an extensive field for the welding of special metals and alloys that are difficult to weld with the ordinary welding processes.

Arc-Welded Metal Railroad Ties. Metal ties have been considered for a long time as a logical substitute for wooden ones. The main obstacle that has stood in the way has been the cost of the steel. Mr. William Dalton of the Manufacturing Department of the General Electric Company conceived the idea of constructing such a tie out of worn rail. The Delaware and Hudson Railroad Company has installed in their Colonie Shops an automatic welding machine for fabricating these ties. Using scrap rail and scrap angles in the place of new steel makes it possible to produce a stronger, longer-lived, and cheaper tie than the present treated wooden tie. (Fig. 1.)

Metallurgical Study of Steel Plate and Electrode Material. Not enough importance has been placed on the metallurgical study of welding and the choice of materials used. Good weldable steel, together with good electrode material, has such a marked effect upon the weld that a careful metallurgical study of plate stock, electrode material, and of the weld itself is warranted. The results of this study should be embodied in rigid specifications.

There are at present two outstanding men who are devoting their time to this study. Mr. C. A. McCune of the American Chain Company, chairman of the Welding-Wire Specification Committee of the American Welding Society, is making an exhaustive study of the effect of various materials in welding-wire, with the aim in view of finding the best ingredients for each application. Mr. G. R. Brophy of the Research Department of the General Electric Company, a member of the Committee on Specifications for Steel

*Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

FIG. 1.—ARC-WELDED METAL RAILROAD TIE.

for Fusion Welding, for the American Society for Testing Materials, is studying suitable plate stock for welding.

The findings of these two committees should be of great value to the users of metallic-arc welding.

Figure 2 is a photograph of a deep-etched specimen of welding. It shows two beads and the extent to which the plate is affected by the heat of the arcs. It also shows the refining of the grain structure of the first bead by the heat of the second.

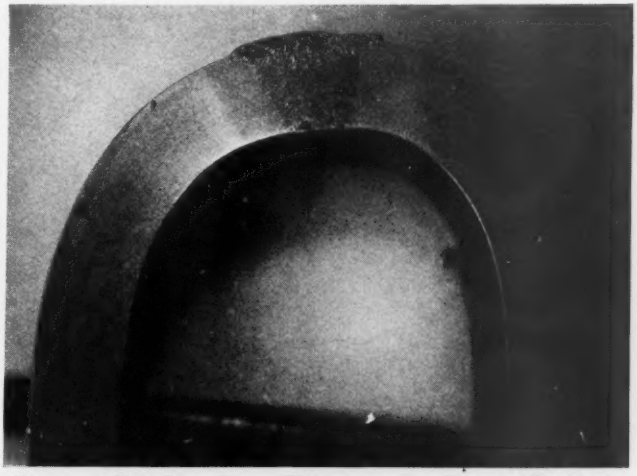


FIG. 2. — HALF-INCH PLATE WELDED BY THE GENERAL ELECTRIC METALLIC-ARC PROCESS.

Replacement of Castings by Welded Steel Plate. At the present time rapid strides are being made by machine manufacturers in the substitution of fabricated steel in the place of castings. This has been made possible by the use of metallic-arc welding for joining the plate and rolled sections.

In our own factory, nearly all of our large water-wheel-driven generator frames are fabricated from steel and quite a percentage of our large direct-current motor frames are rolled from slabs and formed by welding. Rotors, machine bases, bearing-pedestals, and bearing-bracket supports are being developed for welding as rapidly as possible. Large pattern-storage buildings and iron foundries are being transformed into welding or machine shops. (See Figs. 3 and 4.)

Pipe Welding. The utilization of metallic-arc welding in fabricating pipe from steel plate as a substitute for riveted cast-iron, hammer-welded, and lock-bar pipe, is one of the most important developments in welding at the present time.

The welded pipe has the advantage over the riveted pipe in that it has

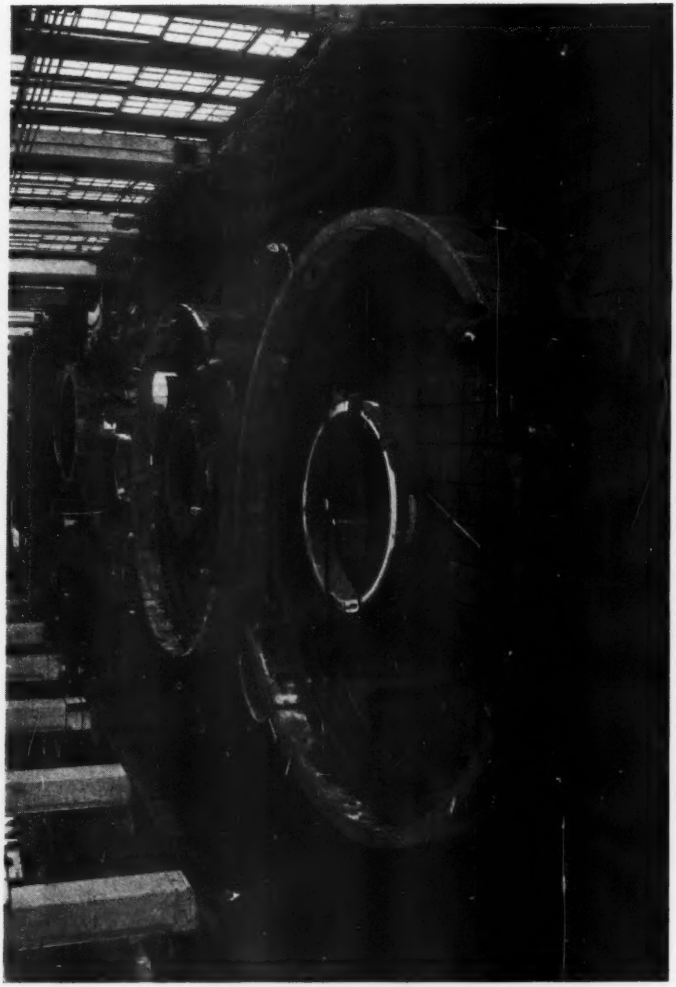


FIG. 3. — WELDING GENERATOR AND MOTOR FRAMES.

a smooth surface on the inside and can be made of smaller diameter for the same flow of water, thereby saving not only the metal, due to the decrease in size, but also the metal of the lap joints necessary for riveting. It has the advantage over the cast-iron pipe in that it can be distorted without breaking, and is made with thinner walls. It has the advantage over the lock-bar in that the installation cost for apparatus for manufacturing is much less and the actual cost of making the joint is less. It has the advantage over the hammer-weld for the same reasons as for the lock-bar type.

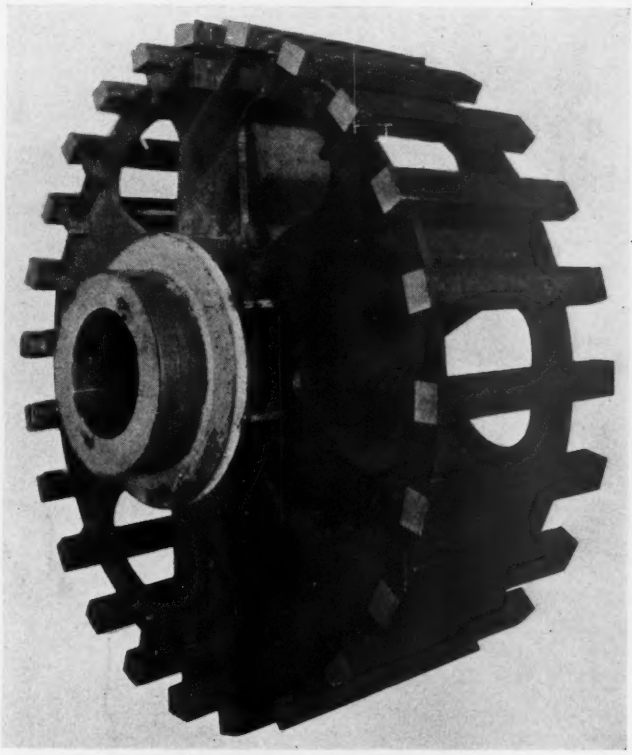


FIG. 4.— FABRICATED ROTOR OF 1 000-H.P. REVERSING STEEL-MILL MOTOR.

The greatest progress in welded steel pipe has been made along the Pacific Coast. Several long pipe lines have been welded and installed by the Western Pipe and Steel Company, the Steel Tank and Pipe Company, the Beall Tank and Pipe Company, and others. Many of these lines have been in service several years and have given a good account of themselves. In the central part of the United States at the present time a pipe line 200 or 300 miles long for carrying natural gas from the oil fields to points of dis-

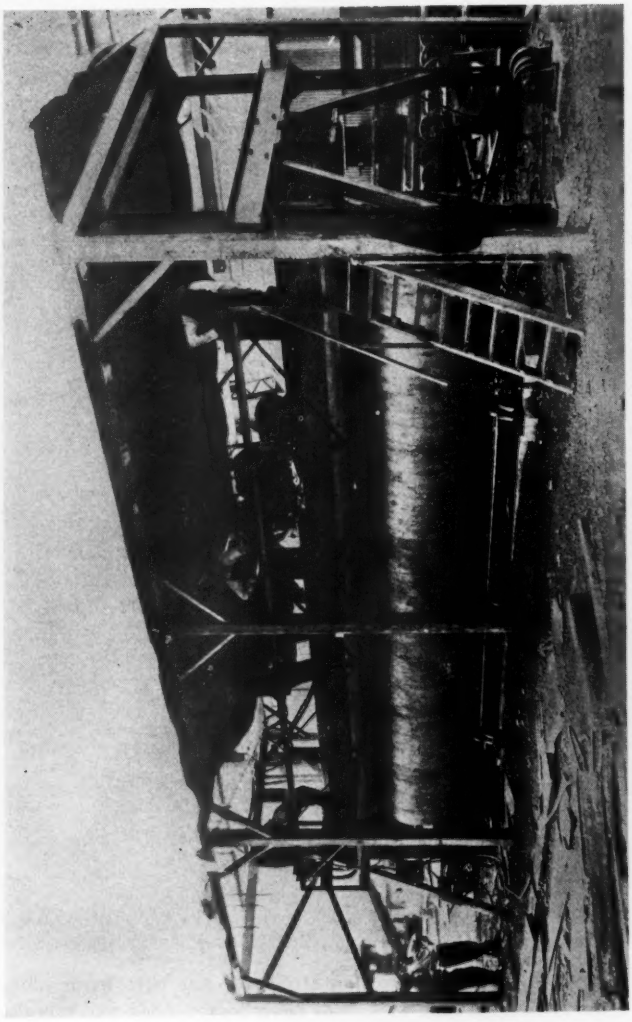


FIG. 5.— WELDING 30-ft. PIPE AT THE PLANT OF THE NEWPORT NEWS SHIPBUILDING AND DRY DOCK CO., NEWPORT NEWS, VA.

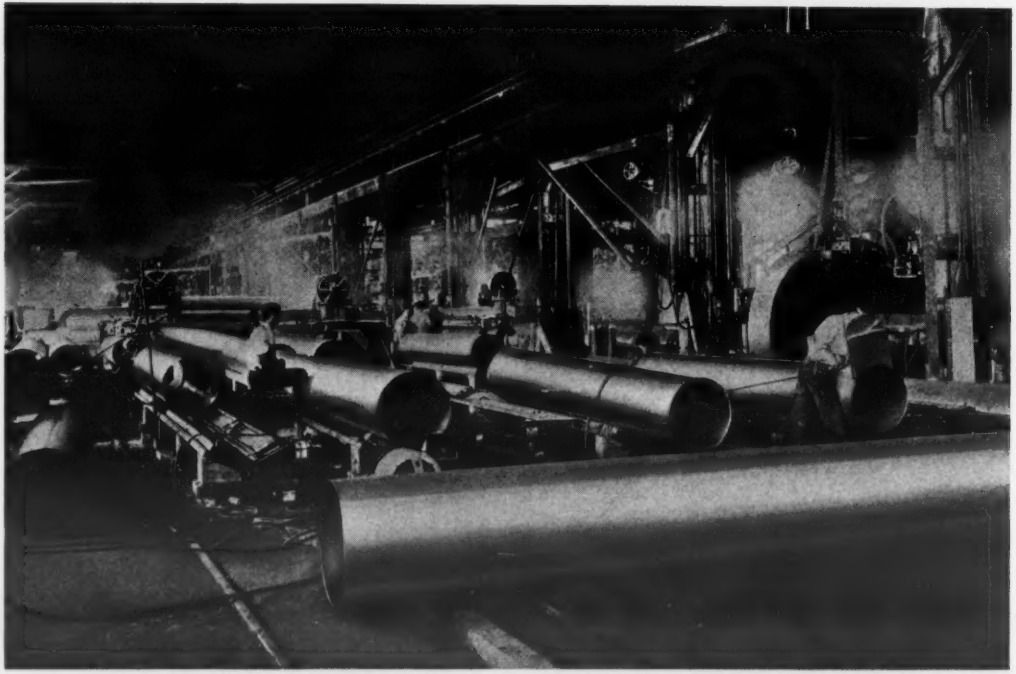


FIG. 6.— WELDING PIPE AT THE PLANT OF THE WESTERN PIPE AND STEEL CO., SOUTH SAN FRANCISCO, CAL.

tribution is being installed. This is being metallically arc welded at the plant of the A. O. Smith Corporation. Coming to the Atlantic Coast, conservative old New England is at the present time building a metallic-arc welded steel pipe line for carrying water from the Proven Mountain Reservoir, located in the mountains seven miles distant from the city of Springfield, Mass., down to the Connecticut River; then under the Connecticut River into the city of Springfield. This pipe line ranges in diameters from 54 in. down to 36 in., in thicknesses from $\frac{1}{2}$ in. to $\frac{5}{16}$ in. and is constructed in lengths of 30 ft. The pipe is being fabricated by the Walsh's Holyoke Steam Boiler Works of Holyoke, Mass. The company, in order to fabricate this particular line and to be in a position for future lines, has installed for doing the work the largest pipe-welding equipment in the world. Their pipe-welding machine is capable of handling pipe in any length up to 36 ft., and in diameter up to 7 ft., with a thickness of plate up to $\frac{5}{8}$ in. They have installed 36-ft. rolls, a 36-ft. planer for forming the edges of the plate, a 36-ft. pipe-testing machine, and an electrically heated 40-ft. dipping vat.

The Springfield pipe line is to be made of Lukens fire-box steel, and exhaustive demonstrations and tests were made for Mr. E. E. Lochridge, Chief Engineer of Water Works of the city of Springfield. The welds are to be made by the multiple-arc automatic arc-welding process which uniformly developed in tension-test practically the full strength of the plate stock.

The Newport News Shipbuilding and Drydock Company at Newport News, Va., has installed an automatic pipe-welding machine for welding large-diameter pipe up to 30 ft. in length. This machine also uses the multiple metallic-arc welding-process, the same as the machine at Holyoke. The photograph of the deep-etched weld in Fig. 2 shows the nature of the welds being made both at Holyoke and at Newport News. (See Figs. 5 and 6.)

(*For discussion of this and other papers on welding, see p. 42.*)

THE METALLURGY OF WELDING-WIRE.

BY C. A. MCCUNE.*

[*Read December 14, 1927 at the Welding Meeting of the Affiliated Technical Societies of Boston.*]

All authorities are agreed that a properly made weld involves good base metal, suitable metal to be welded, good welding-wire, a trained operator, and good equipment. In these days of automatic electric welding, the personal element of the operator is dispensed with, and by this elimination there is a contradiction of the old fallacy that 85 per cent. of the success of satisfactory welding is due to the operator. It is naturally essential, however, in manual welding, that the work be performed by a skilled operator.

Satisfactory welding apparatus is readily obtainable today. The majority of welding operators are capable men but, unfortunately, the base metal which is not always suitable for welding must be taken as received, and the welding-wire is a specialty. While my subject deals only with the welding-wire, the other points mentioned are involved as fundamentals. For this reason, then, perhaps a more suitable title to this paper would be "Some of the Things Revealed by a Research Study of Welding-Wire," and in this I will attempt to show some of the things we have been studying over a period of years that indicate the important position welding-wire occupies in the art.

Some time ago an effort was made to determine what constituted an unsatisfactory welding-wire as well as a satisfactory one. About twenty groups of wires were secured from various sources, these wires being submitted with the statement that good welds could not be secured with them. Hundreds of specimens taken from these wires were examined for chemical analysis, physical properties, micro-structure, and weldability. The materials involved those used for both gas and electric welding.

In some cases the chemical analysis showed the material to be what could be considered a very good grade of metal and in other cases a quite average grade. The carbon content, for instance, ranged from .02 to .20 per cent. The tensile strength varied from 40 000 to 100 000 lb. per sq. in. The elongation varied from 2 to 30 per cent. for material intended for the same purpose. The microscope revealed structures that were all over the map, from very well annealed to hard-drawn, and from clean to very dirty metal. The weldability tests bore out the fact that these metals were unsatisfactory for welding purposes. Some attempts were made to determine the gas content of these wires, but due to lack of sample we were not very successful in that respect. However, the point is that none of the

*Director of Research, American Chain Company, Bridgeport, Conn.

FIG. 1. — Appearance of Poor and Good Welding-Wire after Applying the Flame Test.

standard methods really showed definitely why the wires were unsatisfactory.

For some years we have been using what has been termed the "flame test," and by this test, which consists simply in melting down the surface of wire with a small oxy-acetylene flame, we were able to see some of the things that were causing imperfect welds. The flame test showed that the metal in unsuitable wire boiled with a disturbing action when melted, while the metal in a satisfactory wire melted quietly and smoothly without any evidence of gases or other inclusions. (See Figs. 1 and 2.)

By using poor welding-wire, it was possible to make what appeared to be a satisfactory weld, *i.e.*, from all optical observations there was nothing to indicate on the surface that the weld was other than a satisfactory one. When, however, the weld was cut in two the defects that were apparent in the wire were found embodied in the weld. The effect of welding-heat on electrodes was observed, whereby it developed that the heat used in melting down the electrode affected the structure of the electrode itself to the extent

Top View of Weld.

Bottom View of Weld.

Section through Weld.

FIG. 2. — APPEARANCE OF COMPLETED WELD.

of developing seven different structures in a distance of only $\frac{3}{16}$ in. (See Fig. 3.)

After observing these results it is natural to ask: "What is a satisfactory welding-wire, how can a satisfactory welding-wire be specified, and what are the means for checking the wire against specifications?" In answer to the first question, it is evident that a satisfactory welding-wire must be free from excessive impurities such as gases, slag, etc.; and for electric welding a special added requirement is that the structure be such that the arc will be properly directed. It is difficult to specify such requirements. The only attempts made now to cover welding-wire by specifications are that the usual elements, such as carbon, manganese, phosphorus, sulphur and silicon, be limited. Experience shows that this is not sufficient. It is necessary to add other requirements, but just what these are has not been thoroughly defined. The flame test could be included as it is easily and rapidly made and would give a clear indication of what might be expected in the use of a material. This flame test can also be produced by an electric welder in which the electrode is frozen to the base metal, holding it there until it reaches the melting-point. The same characteristics will be observed by this method as in the gas flame test.

Within the past year, in my contact with those having to do with specifications outside of the American Welding Society, I have found some who believe that a better welding-wire would be secured by reducing the sulphur content, for instance, from .045 to .03 per cent., and that juggling the carbon content around would probably help; but we know that neither of these contribute very much, if anything, in the assurance of a satisfactory welding-wire.

FIG. 3. — Micro-Structure of Heated Electrode. Seven different structures can be identified in a distance of $\frac{3}{16}$ inch.

I have tried in this paper to bring to your mind the need of the careful selection of welding-wire, and I trust that whatever evidence I have been able to offer will lend further encouragement to the study of this very important factor in successful welding.

(*For discussion of this and other papers on welding, see p. 42.*)

REPLACING CASTINGS AND FORGINGS BY STEEL ELEMENTS CUT TO SHAPE BY AUTOMATIC SHAPE-CUTTING MACHINES.

BY ADOLF KREBS.*

[*Read December 14, 1927 at the Welding Meeting of the Affiliated Technical Societies of Boston.*]

If we want to judge the importance of a new industrial process in a common-sense way, we must get an idea first of its possible commercial results, and second of the extent of its field of application. If we add these two main items, we get about the sum total of its commercial value.

The modern tendency is to develop and use material of the highest strength and ductility combined with lowest cost and lowest weight. With iron constructions, cast-iron shapes cost about seven cents to nine cents per pound, and cast steel still more, whereas rolled steel of materially higher strength and ductility costs only two cents to four cents per pound. Basing constructions on rolled steel instead of cast-iron castings, we therefore pay only about one-third per weight and need only one-half the weight to get the same strength and a higher ductility besides. In replacing castings by steel, we therefore start right in with an initial advantage of about 1:6 in cost of material. Of course, this extraordinary saving is somewhat reduced, because we must first cut the shapes out of rolled or pre-forged stock so as to manufacture those elements which replace the purpose of the castings.

However, the more exact, the cheaper, and the quicker we can produce these steel elements and the less surplus material can be left for their ultimate finishing, the closer we come to the 1:6 proportion of saving. Moreover, we always keep the great advantage of lower weights which reduces handling and transportation costs and also the advantage that steel withstands rough handling better than cast iron. Our initial advantages therefore can be listed as follows:

1. Lower weight.
2. Lower cost per pound.
3. Higher quality.
4. Less breakage.

But this is not all. If we have to keep in stock only regular rolled material, ready to be used for a great variety of purposes and at a moment's notice, then we are highly independent of foundries. We also eliminate the stocking up of great and bulky quantities and varieties of cast shapes. Thus we get along with less storage facilities. Moreover, the capital investment is smaller and so are the interest and the general factory expense.

*Consulting Engineer, Boston, Mass.

Add to this the reduction in the number of patterns, their high cost, their storage, their maintenance and all the other less visible but very actual expenses, then we can list as additional advantages:

5. Lower and simplified inventories.
6. Lower stock investment.
7. Fewer patterns and molds.
8. Decreased floor space.
9. Lower factory general expense.

These are the possible commercial results.

Add to these the possible field of application, which is enormous, and you cannot fail to see the astounding prospects. But let us consider a few representative examples:

Fig. 1 shows an hydraulic press made by the Pacific Steel Boiler Corporation for bending $\frac{3}{8}$-in. boiler plates for fire-box walls. The whole structure up to the hydraulic cylinders is made out of rolled steel cut to shape, and the steel elements are welded together. The cost was about one third that of a press of conventional construction. The entire labor cost was less than the patterns would have cost to make the castings. You will easily understand that a steel element construction can easily and quickly be repaired in case of accident. The press weighs 70 tons and works with 1 750 lbs. hydraulic pressure.

Fig. 2 shows a large condenser frame of one of our large electrical concerns, 19 ft. in diameter and built entirely out of steel plate shaped by cutting and welded together. It is easy to figure the saving in weight as compared with a cast frame, and the much lower transportation charges. Furthermore, as the steel elements can be cut to exact size, there is very little machining to be done all over. Finally, if the design is to be changed, it only needs a new setting of the cutting machine and no new, expensive patterns for changed castings.

Fig. 3 shows a shape of a frame element of another prominent electrical concern. The maximum diameter of these frames is 9 ft., all cut out of one single plate. The automatic shape-cutting machine cuts out the irregular lower part from A to B, and an automatic circular cutting machine follows up with the cutting of the other parts outside as well as inside. The inner disk can then be used for cutting smaller frames which may be cut completely with the automatic shape-cutting machine.

Fig. 4 shows another method for making motor and generator frames. A flat piece of steel plate is rolled to a tubular shape, the seam A-B is welded, the legs are cut out by the shape-cutting machine and are welded on. Instead of rolling a solid plate to a tubular shape, it is advisable at times to cut into the plate a number of openings (C) and then to roll it.

Fig. 5 shows steel gears made out of steel rings cut out by the machine and then shrunk on and fastened to a cast hub, or three steel parts — A, B, C — are cut and welded so as to form a complete steel gear blank D.

Fig. 6 shows guards for gear and grinding wheels. Steel plates are spun to form a circular cover and are then cut out to the form wanted, as, for instance, that shown in the picture. Any shape can quickly be turned out or changed over without using costly dies, or without waiting for castings or carrying an enormous amount of diversified shapes in stock.

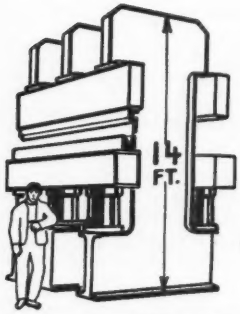


FIG. 1. — Large Hydraulic Press. Weight 70 tons.

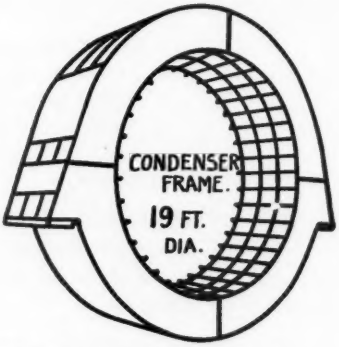


FIG. 2. — Large Electrical Condenser-Frame.

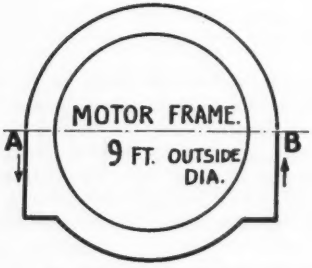


FIG. 3. — Motor Frame.

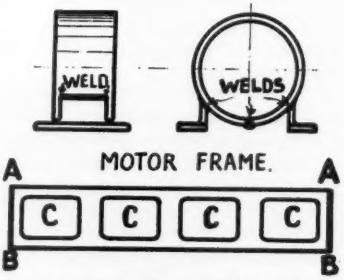


FIG. 4. — Motor Frame, Bent to Shape after Cutting.

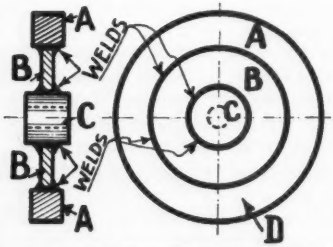


FIG. 5. — Steel Gear Blank (rim, web and hub cut separately and welded together).

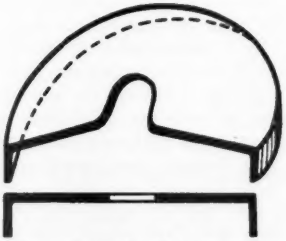


FIG. 6. — Guard for Grinding Wheels. (3 ft. dia., $\frac{3}{8}$ in. thick.)

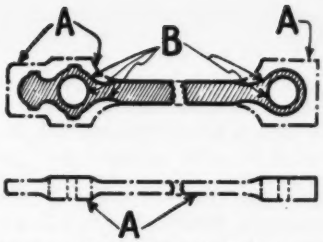


FIG. 7. — Locomotive Slide-Rod (showing pre-forged billet and shape cut out).

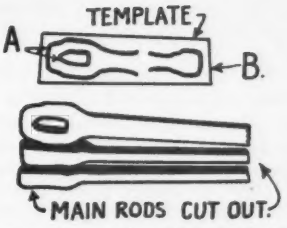


FIG. 8. — Locomotive Main Rod (showing template and cut rods).

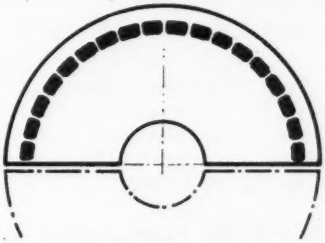


FIG. 9. — Steam-turbine. Diaphragm (2 in. thick).

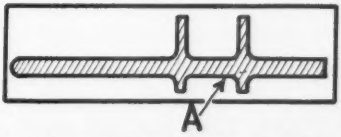


FIG. 10. — "Binder" for Textile Machinery (.60 carbon steel).

However, the replacing of castings is not the only field for machine-cutting. There is at least as great a field in eliminating costly dies when forging, or excessive costly machining. In this case, pieces are either cut completely out of flat stock, or billets are roughly forged to shape and the intricate shapes are produced by machine-cutting. This is illustrated in the following cases:

Fig. 7 shows a locomotive slide rod. The rod is forged to shape A and the cutting machine finishes it up to the ultimate shape B. Very little machining is needed and only on those faces where other machined parts have to be fitted on.

Fig. 8 shows a locomotive main rod together with the template used on the cutting machine to produce it. The template consists of a soft, easily bendable aluminum strip A riveted on a $\frac{1}{8}$-in. steel plate B.

We could continue indefinitely with examples such as these and therefore restrict ourselves to state that some railroad shops carry several hundred of these permanent templates for all kinds of quantity work. Since machine-cutting got into the railroad shops only one-third of their former forge-shop crew is needed to turn out more work than ever before.

We come now to the last part of the technical and industrial value of automatic machine-cutting, and that is intricate work, and to the shaping of high quality and alloy steels.

Fig. 9 shows an intricate steam-turbine part — a so-called diaphragm.

Two disks, each half cut out on the outside, have a number of oval holes cut out on the inside. The thickness is about 2 in. This cutting has to be exact and clean.

Fig. 10 shows that the textile industry is quick to consider a new process. The piece A shown is a so-called binder made out of .60 carbon steel. Formerly it had been roughly cut with a hand-cutting torch and then ground down to size. Now they cut it in a few minutes with the automatic cutting machine, exactly to size, without any further finishing. Anybody can easily figure out that it only takes a few hundred of these cuts of high carbon material to pay for a machine in short order. Of course, they manufacture quite a number of other shapes besides.

Although the remarkable initial advantages, as well as the lower weights and the greater ductility, forcibly point to considerable savings, it is proper to add some figures about the cost of cutting. The following table will give an idea:

Thickness.	Gas Cost per Hour.	Linear Feet Cut per Hour.
½ in.....	about $0.95	about 75 ft.
2 in.....	about 2.00	about 50 ft.
6 in.....	about 4.80	about 24 ft.

Electric power: 1/50 h.p., or less than 1/3 cent per hour.

As to labor cost and speed of production, one single machine in a railroad shop, with one operator and one helper, has cut out over 3 000 shapes within eight months, partly heavy pieces such as locomotive frame sections, links, etc.

Finally, it is interesting to know how clean we can cut and how near we can safely cut to the ultimate line, so as to figure out the cost of finishing. Furthermore, we should know if the machines, once set, always reproduce exactly the same shape. That we can cut clean and reproduce exact shapes you can judge from the cut faces of samples, and if you stack up several pieces of each shape one on top of the other you can see that they fit exactly. The cutting line can be safely set to 1/32 in. of the ultimate shape — with material up to 1 in. thick; and there are people who ask for 1/64 in. For heavier thicknesses 1/16 in. to 3/16 in. allowance is preferable, so as to leave some finishing face where another part has to be fitted in. With high carbon and alloy steels it is wise to leave a little more than with ordinary steel.

In closing, this paper might suggest to the industry to give this fast-oncoming development the attention it deserves and to re-design constructions so as to prepare them for cutting instead of casting. When designing, special thought should be given to avoid welding as far as possible. There is a tendency to overstretch the new field with too much welding. Welding is both costly and slow as compared with cutting. Many pieces can be cut flat and then bent to the ultimate shape. We should conserve to this new process its full commercial value. Present prosperity rides on the dangerous crest of high production, high wages and lean profits, — a so-called "profitless prosperity." We cannot bring down wages without

reducing buying power; but cheaper, lighter, and better material and new methods and designs can remedy the uncomfortable industrial situation.

The author hopes that he has shown what can be done, and a number of progressive plants will show what has already been done. In visiting such plants, however, it is well not to be fascinated with the cutting machines but rather to count the operators and to look at the tons of finished work and the small floor space needed. Then the commercial value will show in the right perspective and it will also show that this paper understates the facts.

Discussion of Welding.

[*Welding Meeting of the Affiliated Technical Societies of Boston, December 14, 1927.*]

Robert Spurr Weston.* I would like to ask someone if the difference in metal and the difference in structure produced by the welding heat will have any effect upon the corrosive action of the water upon the pipe. This question has been raised a good many times. Three conditions of metal are left after welding: a high-carbon steel in the pipe, a low-carbon steel in the weld, and the heat-treated zone between the weld and the pipe itself.

Frank B. Walker.† Possibly I cannot answer your question directly as regards pipe; but in wire-joint welding of rails we have watched the matter of corrosion of the weld itself at the juncture of the weld and the parent metal. Strange to say, there is less corrosion at the juncture than at any other place. We have made many thousands of those joints; they are all outdoors, and all have been subjected to the corrosive action of the elements for eight or nine years. I can't see that they are corroded nearly as much as is the parent metal.

William R. Conard.‡ I think the difference in corrosion is possibly accounted for, to some extent, by the fact that the parent metal usually is a worked or rolled metal, while the weld, or the deposited metal, is a cast metal. The structure, therefore, is somewhat different, and it is well known that cast metal corrodes more slowly than does worked or wrought metal.

Question. In welding steel pipe electrically, can the pipe be heated and bent without destroying the weld?

Mr. Deyoe. I should say that this could be done quite readily and without fear of the pipe being destroyed.

Lewis E. Moore.§ There are several things about welding that to my notion are a little bit unfortunate. For instance, those who first started this process called it "welding." Now, almost everybody has a prejudice against the old-fashioned blacksmith's weld. It was anathema in structural work for years. You will find in all the structural specifications of a few years back the statement that no welds will be allowed; particularly in eye-bar specifications. This statement refers to the old-fashioned blacksmith's weld, which depends on many things, but principally on the skill of the man who makes it. It depends on a number of things that have to be just exactly right. If any of you have tried to make a blacksmith's weld, — and I know some of you have, and I know I have, without much success,— you know how hard it is to do so.

This new process has been named "welding." It is a little too bad that it was not called "fluxing," or something of that sort, because there would not have been so many prejudices to overcome. We might as well look at it with an open mind and form our ideas accordingly. Welding is on its way. It is very useful, and it may eventually take the place of riveting in

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‡Engineer, Burlington, N. J.
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many of our structures. I speak of structures this afternoon, with apologies to the pipe-welding fraternity, because I know more about structures than I do about pipe. But a great deal was said this morning about rivets, and you would think from what was said that rivets were the most reliable thing on the face of the earth, and that you could always inspect a rivet and tell at a glance whether that rivet was good. Now, I have been all through that game; I have been in the shop, and I have worked for railroads, and for a contractor, and I happen to be on the consulting end of it now. I have seen rivets with beautiful hemispherical heads, and I knew that the shank of that rivet was in a hole that was altogether too small for it, and that the holes matched very badly. Of course there were not very many like that in a joint, and the factor of safety would bring them safely home. So that there is nothing sacred about a rivet. Merely because it has a good hemispherical head, and merely because the two heads on the two sides line up and are concentric is no sign that the heads are concentric with the shank of the rivet, because you can't tell that unless you line the rivets up along the joint. Even then there is the chance that they are all offset a little bit. There are a lot of uncertainties in the case.

The weld itself need not be too uncertain. There are two or three simple rules that can be followed which will on rough inspection tell fairly closely what kind of a weld it is. If the metal is spattered around the weld, it is not properly done; if penetration is good, it can be told by looking at the edge of the weld. It is certain that the weld is poor if the metal turns red in about 20 minutes or so from the time the weld is made. A good weld, made with the metal at the proper temperature, will continue to be bright after the work is done. These three tests, while, perhaps, they are not conclusive, will tell a great deal about the integrity of a weld and, at least, will enable one to have some confidence in one's judgment with respect to its goodness.

When one considers the whole thing and looks at it with a reasonably open mind, I think it will perhaps be admitted that as much can be told about a welded seam by looking at the weld as can be told about the shank of a rivet by looking at its head.

MR. HILLIARD.* Most of the comments have been favorable to welding. We are thoroughly sold on welding; in fact, we have put in recently a 14-mile 12-in. line. But we do have breaks occasionally. They generally come in cold weather, when the line is first started up. Doubtless they are due to shrinkage, but that does not account for the whole situation. We have made tests that clearly show to us that shrinkage cannot occasion the breaks we have. The other day, we had a break on a new line; it broke about 11 in. on either side of the weld,— not completely around the pipe. This break at its widest part was about $\frac{1}{16}$in. wide. We made a test last winter by cutting a 12-in. pipe to determine if we could tell just how much spring there would be. The point at which the pipe let go was

*Of the Pawtucket Gas Company, Pawtucket, R. I.

about two inches from the starting-point. This indicates a factor of safety of about 18. If that is true, it does not account for the pipe breaking due purely to contraction. I would like to know if anybody can tell me what other forces or causes enter into the breaking of a welded joint under such conditions.

MR. EDWARDS. We have found in the welding of pipe joints, that if the pipe is properly spaced it helps a great deal in eliminating certain strains. Taking 12-in. pipe, for instance, if it is set up with $\frac{1}{4}$-in. spaces between the joints, by the time it is packed it will pull up to $\frac{3}{16}$ in.; i.e., if you weld at one point you will find the two pipes come together; by the time you get all the way around the edges of the pipe, the edges of that joint will just about meet. This shows that a strain would be set up if the pipe were placed tight together, and it shows the necessity of spacing.

In welding large-size pipes I have always found it advisable in finishing a weld to heat a stretch of pipe about 6 in. back, opposite where the weld is finished, in order to relieve the strains. By doing this and heating the pipe in the cold section, while the weld is cooling, the metal is expanded and moves towards the weld.

We all know that a welded metal is of cast nature, and if the strain is transferred into the rolled metal, which has a stronger fiber, it will be found that the strain in the finished weld is eliminated. In answer to Mr. Hilliard's question it may be that the breaking of a weld about two inches from where it stopped indicates that possibly the strains were locked up at that point; the back heat at that point might have eliminated the strains. I recommend heating on all large-size pipes. With smaller-size pipe one does not have to be so particular about it.

RELINING PAYSON PARK RESERVOIR; CAMBRIDGE WATER WORKS.

BY LEWIS M. HASTINGS.*

[*Read January 11, 1928.*]

The present population of Cambridge is estimated at about 125 000. The average consumption of water, as now estimated, is about 12 m.g.d., or a total of 4 355 million gal. yearly.

This water is obtained from two sources. The first and older supply is Fresh Pond, situated in the westerly part of the city near the Belmont line. The amount of water obtained from this pond is small and, due to the rapid occupation of the drainage area for streets and houses and the consequent removal of the surface water by the sewers being built, this amount is constantly being reduced. By far the greater part of the water consumed by the city is obtained from the watershed of Stony Brook, a branch of the Charles River lying in the city of Waltham and the towns of Weston, Lincoln and Lexington. The watershed comprises about 23½ sq. miles. From the storage reservoirs on this watershed the water is conducted by conduits to Fresh Pond, a distance of about eight miles. Here are located the filtration plant and the pumping station. After the water has passed through the various processes of purification — filtration, aëration and sterilization — it is passed over to the pumping station, where it is forced up to Payson Park Reservoir which is situated upon high ground a short distance westerly of Fresh Pond in the town of Belmont.

A rather curious fact about this operation is that the water starting from the higher and larger storage reservoir at Hobbs Brook, a branch of Stony Brook, runs down to Fresh Pond, a fall of about 164 ft. in elevation, and is immediately pumped up again to an elevation at Payson Park Reservoir but 2½ ft. lower than it was when it started — at first thought a seemingly illogical and unscientific procedure. However, there is abundant reason for this, which will not be discussed here. From Payson Park Reservoir the main supply pipe, 40 in. in diameter, is led directly to Harvard Square and the various distributing pipes in the city.

The reservoir at Payson Park was built in 1894, 1895 and 1896 and was to have the double function of giving increased head or pressure on the pipes and also a good supply of water in store in case of a large fire. The reservoir occupies nearly the whole of a tract of land 11¾ acres in extent and contains, when full, about 43 million gal. of water, having a surface area of 7.4 acres. The average depth of the water is 20 ft. The enclosing embankments are of earth obtained from the excavations and are lined on the inside with concrete of varying thickness.

*City Engineer, Cambridge, Mass.

The floor is also covered with cement concrete. A heavy partition wall of granite is carried across the reservoir, cutting it into two equal parts or basins, each holding about 21½ million gal. of water. The inner slopes were protected by slope paving,— the portions below the old surface of the ground being paved with brick on edge laid in Portland cement. The other portion of the slopes, above the old surface of the ground, but in the embankment, was paved with split quarry-granite blocks laid on a bed of cracked stone. These embankments also contain a core wall of masonry connecting with the inner slope paving of brick, already referred to. The reservoir was commenced in 1894 and partly constructed by a contractor. The work performed by him was so poor and unsatisfactory that in 1895 work was stopped by the water board on recommendation of the engineer, and the reservoir was finished by using day labor and materials bought by the city. The reservoir was finished in 1896 and water put in it that year.

Both basins leaked so badly that it was not possible to put more than 12 or 13 ft. of water in them without starting an amount of leakage which flooded nearby cellars and caused protests from the owners of the property. Several attempts were made to discover just where the larger leaks were, but it was found impossible to do this without tearing down more or less of the embankments and their linings. As this leakage water was not lost but was returned by the under drainage system to Fresh Pond, the financial loss was not a large one at first, the daily amount escaping from the reservoir being about 20 000 gallons. Gradually, however, this leakage seemed to increase, and for the year 1926 it averaged about 500 000 gal. daily. This, together with the increased cost of the water due to filtering, and the desirability from an insurance standpoint of increasing the pressure and the reservoir storage by keeping the reservoir full, led the water board to a decision to reline the reservoir so that it might, with safety, be kept full and without excessive loss from leakage. This matter was under consideration by the water board for nearly ten years.

Various types and kinds of linings were proposed and considered. Several trips were made to the cities where similar work had been carried out, and the water board finally concluded that, on the whole, covering the entire inner surfaces of the two basins with a lining not less than two inches thick and composed of the best American Portland-cement mortar, applied in the form of and known as "reinforced gunite," would be the most satisfactory and durable under the conditions existing in this reservoir. When this decision was reached, plans and specifications were immediately prepared, the work put on the market, and the contract for performing the required work was executed. This work is now substantially completed and the reservoir is now in use and full to the top.

It is my purpose to briefly describe here some of the principal features of the work as carried out. The lining was to be of gunite not less than two inches thick at any point and reinforced in the center with wire mesh. This mesh was of galvanized No. 5 steel wire spaced 4 in. apart in both

directions, electrically welded and weighing about 71 lbs. per 100 sq. ft. In order that this mesh might be kept in the center of the gunite lining, the shooter's helper, with a stick having a bent iron in one end, lifted the mesh to the required height and the gunite was quickly shot in.

The base upon which this gunite lining was to be placed was of several general types and required different types of anchors to hold the reinforcement in place.

1. Concrete-Slab Floor Base. This base was fairly true in surface and the reinforcing mesh was held in place by $\frac{3}{4}$-in. anchor bolts 3 ft. apart in both directions. The conditions on the brick-paved slopes were quite similar.

2. Granite-Paved Slopes. Here the surface was quite irregular, with many openings between the stone blocks of irregular shape. The anchors were of $\frac{3}{4}$-in. galvanized-iron lag screws inserted between the stones. The openings between the stones were filled or choked up with the gunite as it was "shot" on to the paving. The average thickness here was over the required 2 in.

3. Sides of the Partition Wall. These sides were nearly vertical and had a rough "quarry face" exposure. The $\frac{3}{8}$-in. galvanized-iron expansion anchor-bolts were inserted in holes drilled in the wall and the mesh hung from them. Here also the average thickness of the lining was much more than 2 in.

The gunite was specified to consist of one part Portland cement of any one of six named brands of American Portland cement, and $2\frac{1}{2}$ parts of sand; the cement and the sand to be mixed dry in the proper portions, then placed in the "gun" and the water added as required at the nozzle where an air pressure of not less than 35 lbs. per sq. in. was to be maintained. It was found very necessary to keep this air pressure up, for if it was lowered, the velocity of the jet was reduced, and choking and irregular flow of the materials followed. The mixing of the sand and cement was done by a mechanical mixer of an ingenious type, outside of the reservoir, carried by a belt conveyor to the top of the embankment, there screened to break up the lumps and eliminate all coarse sand and other particles, then chuted to the bottom of the reservoir inside, where small auto trucks or "buggies" carried the mixture to "guns" placed on the floor, where the air pressure was raised to about 50 or more pounds. This forced the materials through lines of hose to the nozzle where the operator or "nozzle man" added the water as required to the dry mixture and sprayed or "shot" the mixture with a circular motion onto the prepared surface to be covered. Usually four of these guns were operating at the same time. Figures 1 and 2 show the work in progress.

The spraying or "shooting," as it is called, requires considerable skill and practice in order to produce good, smooth work of an even thickness and without sand pockets, lumpy bunches, ridged over-laps, or other defects.

FIG. 1.—SHOOTING GUNITE ON RESERVOIR FLOOR. PARTITION WALL AND 40-IN. INLET PIPE IN BACKGROUND.

FIG. 2.—SHOOTING GUNITE ON SLOPE PAVING. NOTE THE WIRE MESH IN PLACE.

At first it was found difficult to procure an even thickness on a smooth base. The temptation to run under the stipulated thickness was very great and was often hard to detect. A very simple device proved very useful in this case. It was a stick about 4 ft. long, in one end of which a prod or needle was inserted so as to project just 2 in. from the end of the stick. Any question of the depth of the gunite being applied was quickly settled by the inspector "needleing" it as required, before set had taken place. The amount of "rebound" or loose material and coarse sand not attached in the "shooting" process was quite large, especially so on the vertical surfaces. In "shooting" the partition wall, it was estimated that 20 to 25 per cent. of the material was loosened and fell to the bottom as "rebound." This material had to be carried out of the reservoir, transferred over the bank to the street level and, although of excellent stock, was given to the town of Belmont for use as filling.

The sand used for the gunite came from a bank in the town of Belmont and gave some excellent tests for cleanness and lack of iron or acid. Combined in the usual proportions with cement, it gave results better than the "Standard" or "Ottawa" sands on 28-day tests, when mixed in the usual 1:3 proportions. Tests for fineness showed that a somewhat less amount of finer grains was present in this sand than was found in some other sands. While this might tend to make the gunite less dense than some other sands with more fine grains and so increase its permeability, it was thought that its other good qualities would outweigh those of the other sands offered for use. It is expected that even if the gunite does not show a high degree of impermeability at the first, that this in time may be decidedly improved by silting up of the voids in the gunite, especially in the bottom portions of the lining under considerable water pressure, while the upper portions of the lining will tend to be sealed with the water growths, algæ, etc., of a gelatinous nature, always found at shallow depths. The walls and slope paving of this reservoir were found thoroughly coated at and for some distance below the water line with growths of this nature, which were quite difficult to remove.

The floor of the southerly basin was originally covered with a 6-in. layer of natural cement concrete, part of which was in very poor condition. Before the gunite was placed in this basin, the entire floor was covered with a 6-in. layer of Portland cement concrete. There were approximately 13 800 sq. yd. of 6-in. concrete on this floor. Upon this concrete the 2-in. gunite lining was placed. The total surface area covered by the gunite was about 374 283 sq. ft., or 8.4 acres.

Perhaps some figures relating to the amount of cement required for gunite in the different situations may be of interest. It was found on this work that —

One barrel of cement was required on the floors and brick slopes to make gunite to cover 50 sq. ft. of surface.

One barrel of cement was required on the dividing wall to make gunite to cover 38 sq. ft. of surface.

One barrel of cement was required on the stone slope-paving to make gunite to cover 34.8 sq. ft. of surface.

The contract lump-sum price for doing the entire work was $131 576. As the monthly payments were based on unit prices of the work actually performed, the following scale of unit prices which would produce the lump-sum price, were adopted and were not objected to by the contractor, so they were thought not to be very far out of the way.

6-in. concrete floor @ $2.25 per sq. yd., or $13.50 per cu. yd. of concrete.
2-in. gunite on floor @ $2.15 per sq. yd.
2-in. or more gunite on slopes @ $2.45 per sq. yd.
2-in. or more gunite on partition wall @ $3.15 per sq. yd.
3-in. pipe drain of galvanized iron @ $2.65 per ft.
Vitrified underdrain pipe @ $5.00 per ft.
Elastic joints @ $2.00 per foot.

DISCUSSION.

TIMOTHY W. GOOD.* For the past nine years we in Cambridge have been handicapped in supplying water to our 125 000 people while the available reserve of water was only twelve or thirteen million gal. Today, as a result of the work described by Mr. Hastings, we have the reservoir filled to a depth of about 19 ft., and carrying practically 39 million gal. It is a great boon to the city of Cambridge to have the work finished, and this before the cold weather came. I feel that we have demonstrated to all water-works men that we have found the ideal process for tightening leaky reservoirs.

Mr. Hastings has not described the original trouble we had with the porous bottom in the southerly basin. The lining was of Rosendale cement which developed leaks. Several years ago we put on an inch coating of bitumen. This proved satisfactory while it adhered to the concrete, but water got under the lining, and we were continually troubled with leakage. The leakage was estimated by a pitometer test to be over 500 000 g.p.d. You can readily see the large saving we have made, not only in pumping costs but also in the conserving of filtered water. While no official test has been made as to the tightness of the reservoir, I am confident that the final test, when made, will show that the leakage is below the amount allowed in the contract, namely, 20 000 gal. every 24 hours.

The gunite method, to my mind, is the most wonderful process that water-works men have had placed at their disposal during the past ten years. With a very good mixture of cement being used under a pressure of approximately 40 lbs. and penetrating into every crack, crevice and corner, there is hardly a doubt that the reservoir will not be perfectly tight.

*Superintendent of Water Works, Cambridge, Mass.

The reinforcing wire, designed by Mr. Hastings and constructed under his specifications by spot welding, was a great boon to us, because with the method of fastening to brickwork or to the granite we practically have what I call two complete concrete bowls.

The work was completed within the allotted time and at a cost figure slightly less than that of the appropriation of $145 000. What pleases the City Council, the Mayor and the people of Cambridge, is that the work we have done is satisfactory. The city has had a leaky reservoir for over 20 years; now we have made it completely tight, or as tight as it is humanly possible to make it. In addition to this saving, we are now practically independent, because if we should have a break in our pump for a period of 24 hours, we shall not be compelled to go over to the Metropolitan Commission and purchase water at a rate much higher than our own.

IRON-REMOVAL PLANT FOR AMESBURY, MASS.

BY GEORGE A. SAMPSON.*

[*Read September 14, 1927.*]

The town of Amesbury, Mass., is located in the extreme northeast corner of the Commonwealth of Massachusetts, at an average elevation of 80 ft. above mean low water. It lies on both sides of the Powow River, which joins the Merrimack River two miles to the south, at a point about three and a half miles above Newburyport. Amesbury is mainly a manufacturing community, with automobile bodies one of the chief products. The industries require a considerable amount of water, a portion of which is supplied by the town.

Population. The rate of growth in population has been quite irregular during the past century, due to the growth and decline of various transitory industries, and is of sufficient interest to record in the following tabulation:

Year.	Population.	Year.	Population.
1830	2 445	1900	9 473
1840	2 471	1910	9 894
1850	3 143	1920	10 036
1860	3 877	1925	11 229
1870	5 581	1930	11 650 (estimated)
1880	3 355	1940	12 650 (estimated)
1890	9 798	1950	13 650 (estimated)

Water Consumption. For the year 1925 the water consumption, as measured by a 12-in. x 4-in. Builders' Iron Foundry registering-indicating-recording Venturi meter, was as follows:

Average daily consumption, 709 600 gal. or 63.2 gal. per capita per day.
Maximum daily consumption on December 29 ..... 1 150 000 gal. per day.
Maximum weekly consumption December 23 to 29 ..... 856 000 gal. per day.
Maximum weekly consumption August 30 to September 5 ..... 848 000 gal. per day.
Maximum monthly consumption September ..... 752 100 gal. per day.

For the year 1950 the estimated population is 13 650 and the daily per capita consumption is assumed at 80 gal., giving an average daily consumption of 1 092 000 gal. and a maximum daily of 1 640 000 gal.

Water Supply System. The source of supply for the town of Amesbury is a ground water obtained from driven wells located in the valley of the Powow River, about two miles west of the business district. The 50 wells in use at the beginning of the improvements to the supplying system were of the type common to New England, being $2\frac{1}{2}$ in. in diameter, driven into a water-bearing stratum of sand or gravel, and connected to

*Of Weston & Sampson, Consulting Engineers, Boston, Mass.

1 800 lineal feet of 6-in. to 12-in. cast-iron suction-mains leading to the pumping station. The maximum yield of this system during an extended dry period was found to be about 800 000 gal. per day. This fact was very forcibly demonstrated during the latter half of the month of December, 1926, and first half of January, 1927, when immediately prior to the final connection of additional wells with the system the triplex pump at the pumping station, which furnished the town with water, ran every minute for thirty consecutive days with the suction lift increasing to a final vacuum of 25 in. of mercury and the storage reservoir dropping slowly but steadily until only 3 or 4 ft. in depth remained. The rate of pumping began at about 875 000 gal. per day and at the end of the period, due to an increased slippage because of the greater suction lift, had decreased to about 800 000 gal. per day.

A combined sand and air chamber, 4.5 ft. in diameter by 7 ft. in length, was provided in the 12-in. suction-main within the pumping station. The air from the well system was removed by two reciprocating air pumps run continuously and operated by belts driven from the crank shaft of either triplex pump.

There were two pumping units for supplying the town with water. The first unit, installed in 1910, was a Rumsey vertical triplex pump, gear-connected to a 35-h.p. General Electric motor with a normal capacity of 700 g.p.m. The second unit, installed in 1913, was a Deane vertical triplex pump, gear-connected to a 75-h.p. General Electric motor with a similar capacity. The Deane was equipped with a 75-h.p. motor in order to operate against the additional head introduced whenever the high-service fire reservoir was opened into the distribution system.

The pumps discharge into a 12-in. cast-iron force-main, leading to the business section of the town and branching off to two low-service storage reservoirs located a total distance of about 15 000 ft. from the pumping station. The force main was cleaned a few years ago by the National Water-Main Cleaning Company, with a considerable decrease in friction and a saving in pumping head.

The low-service reservoirs have a capacity of 300 000 and 700 000 gal., are situated a few hundred feet apart and are connected together by a cast-iron main. The elevation of the flow line of the reservoirs is only 77 ft. above the floor of the pumping station, and the resulting pressures throughout a considerable portion of the distribution system are inadequate for fire protection.

The high-service reservoir has a capacity of 1 million gal. and is located above the low-service reservoirs, with its flow line 187 ft. above the pumping-station floor. Whenever a fire occurs the high-service reservoir is thrown into service by opening an electrically operated, remote-control hydraulic valve, thereby increasing the pressure by about 48 lbs.; and this sudden change in pumping head may occur at any minute of the day without any warning to the engineer at the station.

Quality of Water. The sanitary quality of the water has always been excellent, but the iron content, unobjectionable in the beginning, increased rapidly with continued draft on the wells until in 1925 it had reached as high as 7 p.p.m., or 58 lbs. of iron per million gal. of water delivered to the distribution system. Complaints from the water-users became so numerous and insistent, especially on those occasions when the fire reservoir was turned on, with a resulting high velocity through certain mains and sometimes a complete reversal of the direction of flow in others, that early in 1926 the town decided to construct an iron-removal plant, to extend its driven-well system in the Powow River Valley and to install new pumping equipment, for which an appropriation of $150 000 was voted.

The writer's firm was engaged on April 17, 1926, to prepare plans and specifications and to supervise the construction of the proposed improvements. Fortunately the problem of iron removal and additional driven wells had been under investigation by the State Department of Public Health and by engineers employed by the town since early in 1924, and the information obtained from these studies was of great assistance in our studies. It had been found by test wells covering all the promising water-bearing areas within the town that it was impracticable to locate another source of supply, and additional test wells in the valley of the Powow River, near the existing wells, all indicated a large amount of iron in the water. It was therefore evident that the best solution called for an extension of the existing driven-well system and the construction of an iron-removal plant. Accordingly, surveys were made, experiments conducted to determine the extent of aëration and filtration required, and other information secured for the final design.

Iron-Removal Plant.

Contract drawings and specifications were ready on May 29, 1926, and on June 8 the following proposals were received and opened:

Bidder.	Amount.	Bidder.	Amount.
A	$76 200.00	D	$95 586.25
B	78 192.00	E	102 000.00
C	79 322.00	F	104 000.00

The contract was awarded on the same day to S. C. Sperry Company, Inc., the lowest bidder, for the sum of $76 200.00. The plans were approved by the Massachusetts State Department of Public Health on June 15, and construction work was begun the following day.

The iron-removal plant is located adjacent to the pumping station, where the topography was unusually favorable to the structures. The excavation encountered was sand, free from water, and compact enough to provide a firm and uniform foundation. The work progressed satisfactorily so that on January 21, 1927, treated water was first delivered to

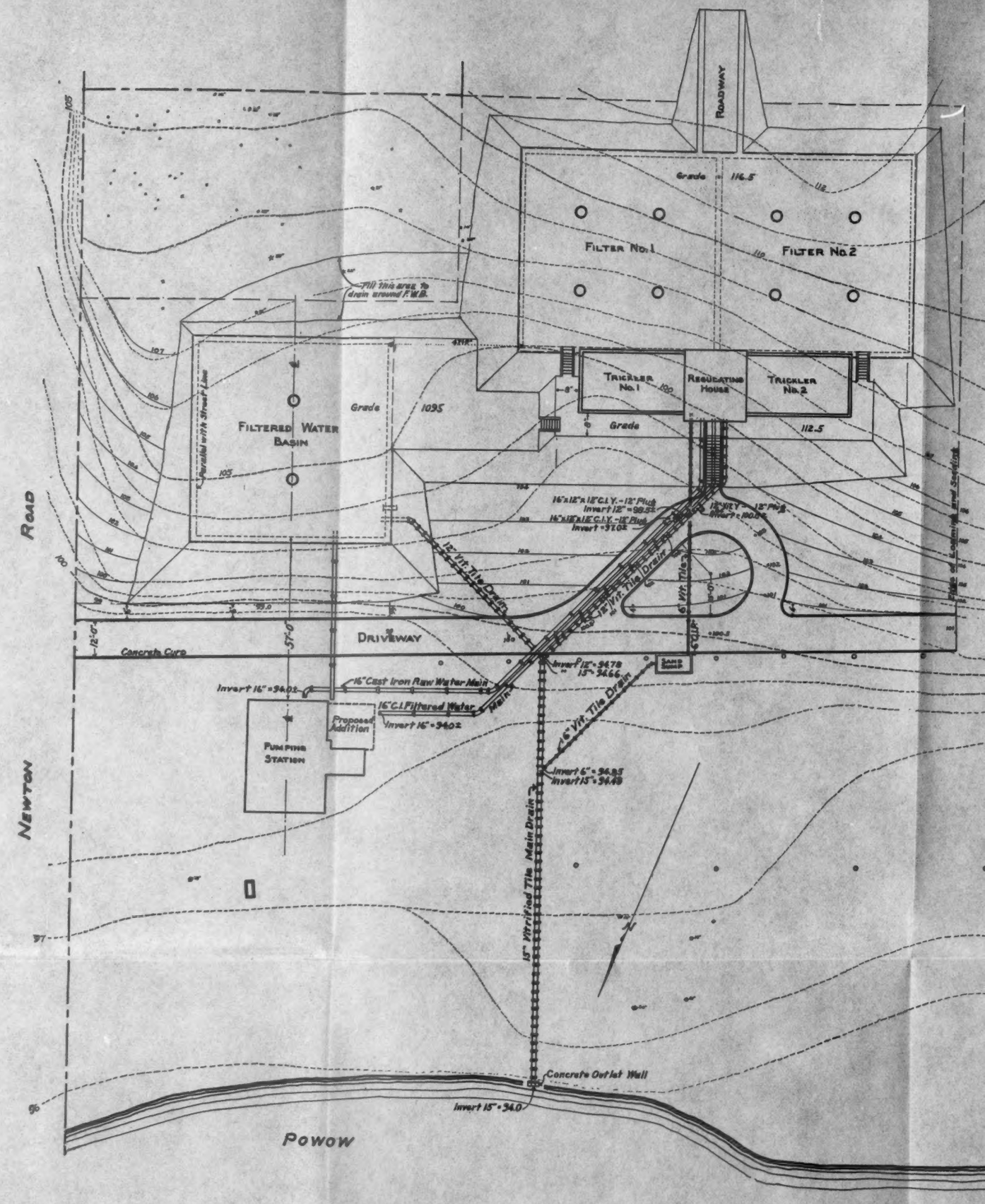
the town and on February 1 the iron-removal plant was regularly placed in operation.

The plant has a normal capacity of 1 050 g.p.m., or 1.5 m.g.d., although it is expected that a wholly satisfactory effluent may be obtained at a rate of 2.0 m.g.d., or more. The treatment plant comprises the following parts and processes, the general arrangement being shown in Plate I.

Aërators. There are two aërator units, each 20 ft. by 36 ft. in area, the purpose of which is to increase the oxygen content of the ground water and at the same time to decrease the carbon-dioxide content. Each aërator consists of a grid of cast-iron and wrought-iron piping, with 45 2-in. risers, terminating in bronze nozzles having a concave top perforated with 25 5/32-in. diameter holes arranged to give uniform distribution. The height of the streams above the top of the nozzles is 2.5 ft., requiring a head at the nozzle of 4.0 ft. for the present operating rate of 1.5 m.g.d. By enlarging the holes to 3/16-in. the same head conditions may be maintained for a rate of 2.0 m.g.d. For this type of nozzle it is important that the diameter of holes be based upon the character of the water to be aërated, in order to avoid clogging and at the same time to secure proper aëration.

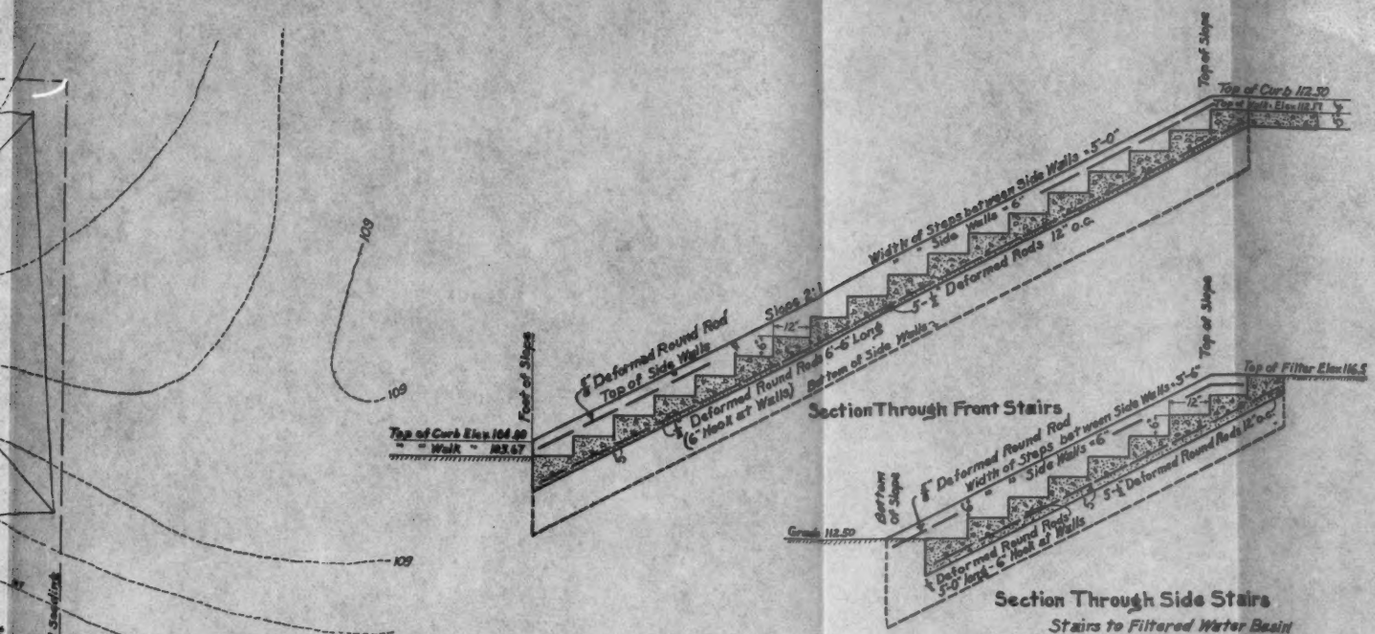
Tricklers. The aërator nozzles discharge upon coke filters through which the water trickles by gravity. The purpose of the tricklers is to further the aëration and to provide contact of the water with the coke beds to better prepare it for final treatment. Each trickler is 20 ft. by 36 ft. in area, thus giving a normal rate of 0.72 gal. per sq. ft. per minute, or 45 million gal. per acre per day. With the plant operated at 2.0 m.g.d. the rate would be 60 million gal. per acre per day. The coke is six feet in depth and consists of a hard by-product coke of egg size (2½ in. to 1½ in.), thoroughly washed with a fire hose stream before placing in the tricklers, with the bottom 6-in. layer of a size to be retained on the slats. The coke beds are supported on 2-in. x 6-in. reinforced concrete slats, 4 in. on centers, resting on I-beams encased in concrete. The depth and size of the coke is selected to give proper preliminary treatment and to allow washing out the accumulated iron and organic deposits at intervals of from 2 to 4 years by means of a fire hose stream without removing the coke.

Subsiding Basins. Each trickler discharges into a concrete subsiding basin 20 ft. by 36 ft. in area, having a depth of water of 10.5 ft. A conical overflow at an elevation 6 in. above the normal flow line and discharging into the main drain is provided for each basin, which also protects the filters from flooding. The basins have 10-in. drains at the bottom, discharging into the main drain and controlled by gate valves. Semi-circular openings are cast in the three exposed concrete walls supporting the tricklers, between the tricklers and the subsiding basins, to give additional aëration. The basins serve the double purpose of subsidence for the aërated water, which removes a considerable amount of iron oxide, thereby relieving the filters to that extent, and of receiving basins for cleaning the tricklers. The subsiding basins have a capacity of 56 500 gal. each, or 1 hr. and 45 min. storage

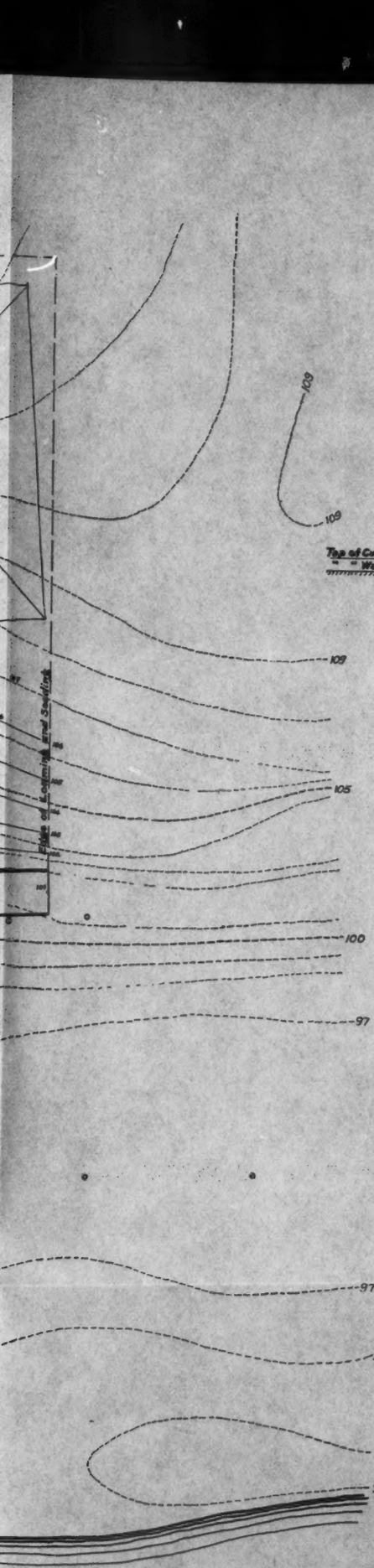


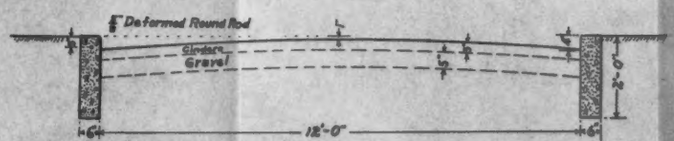
GENERAL PLAN OF IRON-REMOVAL

PLATE I.
N. E. W. W. ASSOCIATION.
VOL. XLII.
SAMPSON ON
AMESBURY
IRON-REMOVAL PLANT.


Top of Slope
Top of Curb 112.50
Top of Walk Elev 112.71
Width of Steps between Side Walls = 5'-0"
Side Walls 6"
5-½ Deformed Rods 12" o.c.
Slope 2:1
12"
½" Deformed Round Rod
Top of Side Walls
½" Deformed Round Rods 6'-6" Long
(6" Hook at Walls)
Bottom of Side Walls
Toe of Slope
Top of Curb Elev 104.80
Walk 103.67
Section Through Front Stairs
Top of Slope
Top of Filter Elev 116.5
½" Deformed Round Rod
Width of Steps between Side Walls = 5'-4"
Side Walls = 6"
5-½ Deformed Round Rods 12" o.c.
Bottom of Slope
Grade 112.50
½" Deformed Round Rods
3'-0" long 6" Hook at Walls
Section Through Side Stairs
Stairs to Filtered Water Basin
Similar except Length is 2ft Less

CONCRETE STAIRS

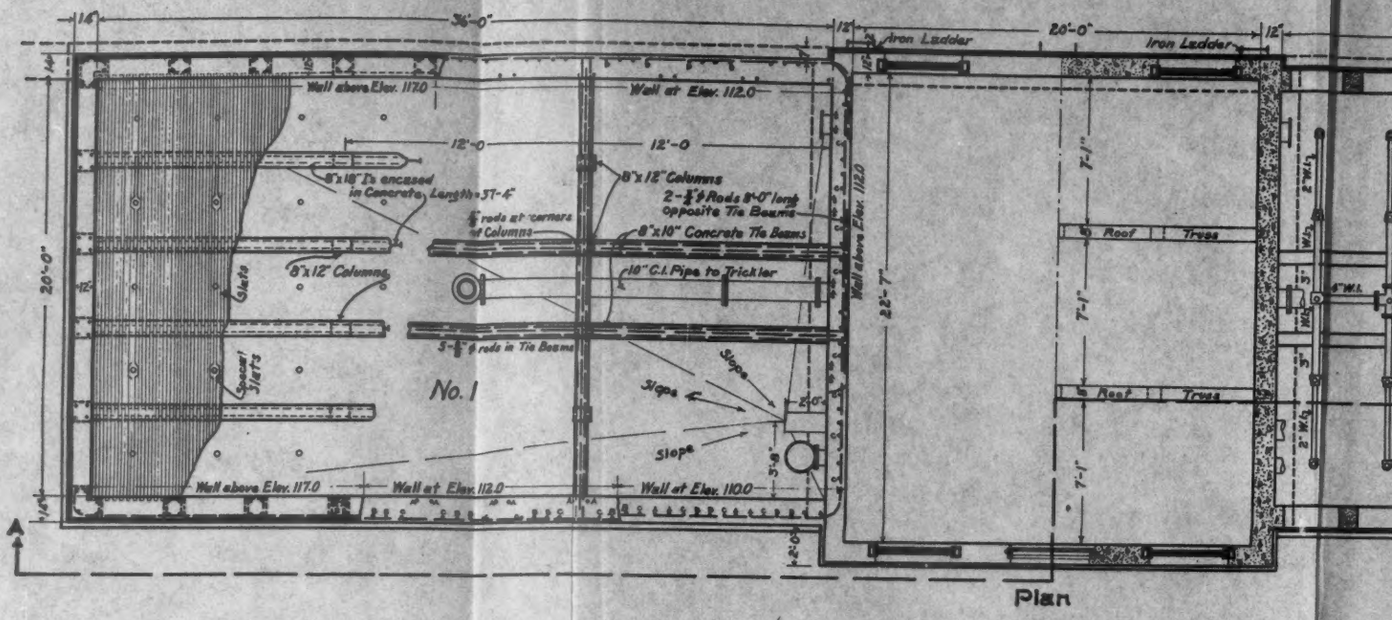


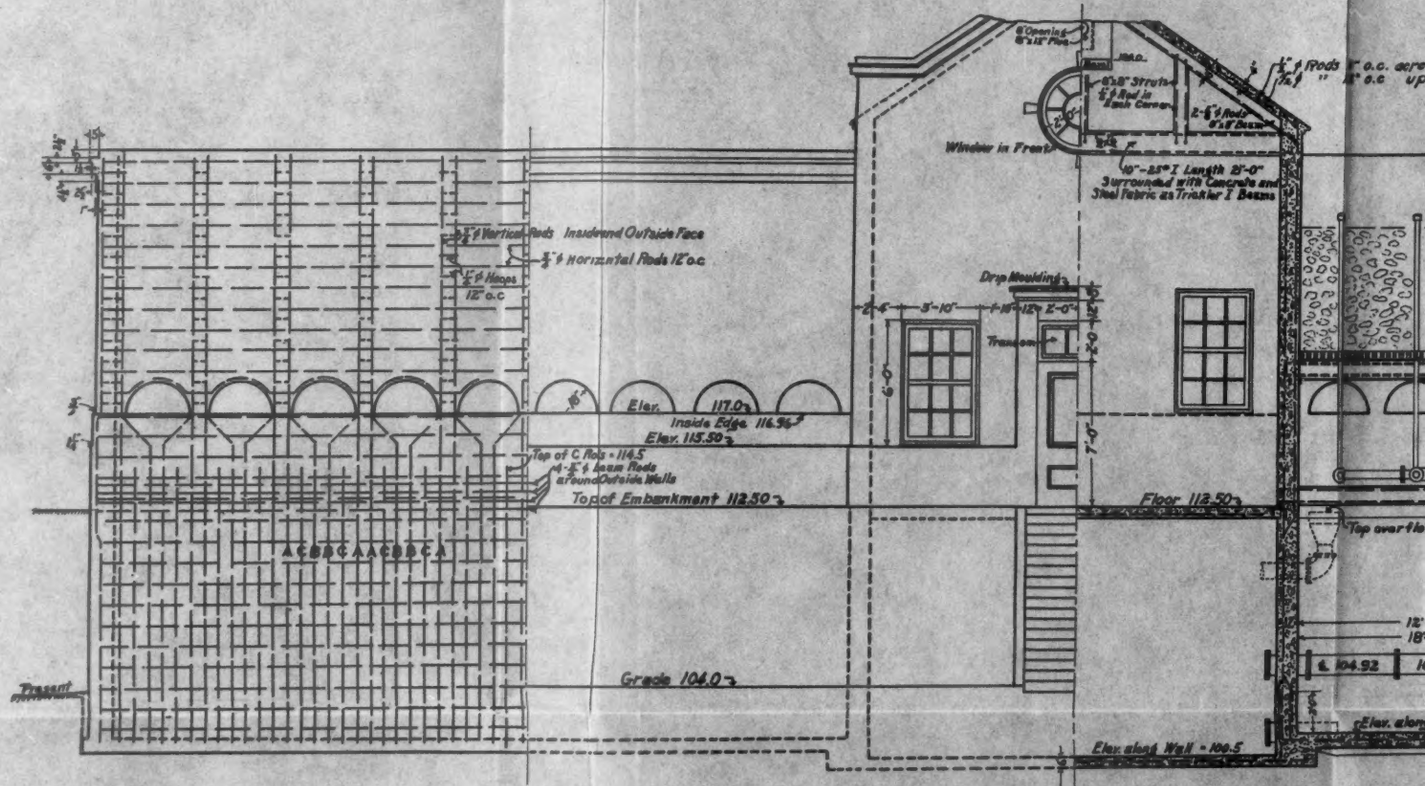


SECTION THROUGH DRIVEWAY
AND CONCRETE CURBS

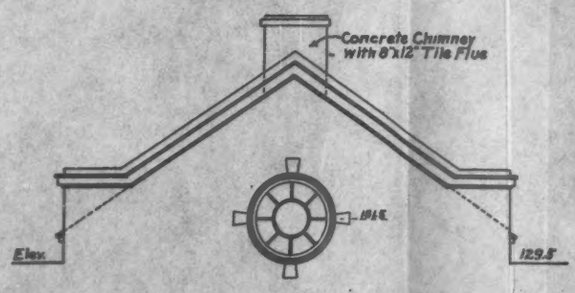
Note:
Present Contours Shown Thus ------
Proposed " " " ——

EMOVAL PLANT, AMESBURY, MASS.

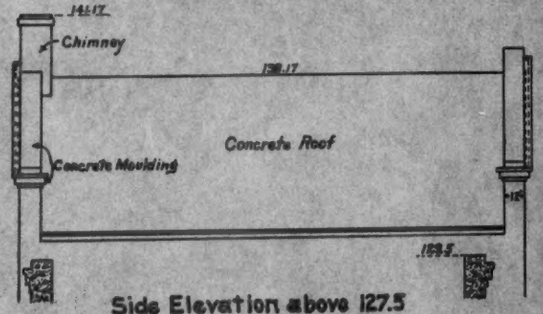




Sectional Elevation on A-A



Front Elevation above 129.5

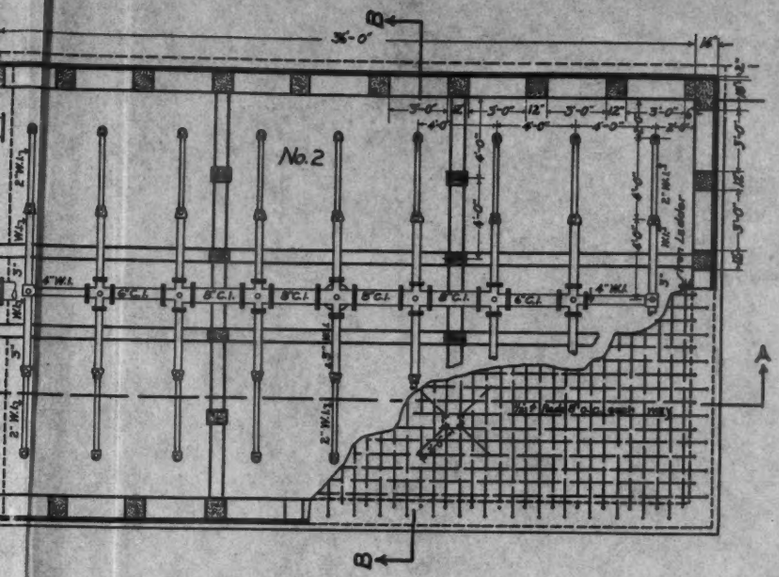


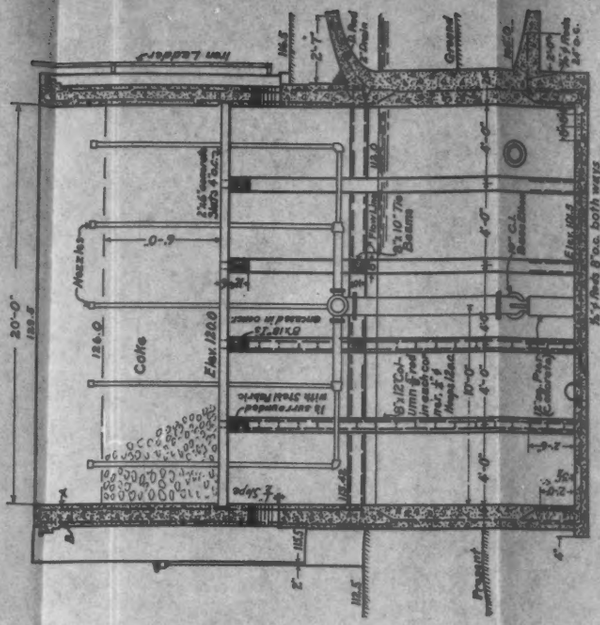
Side Elevation above 127.5

REGULATING HOUSE

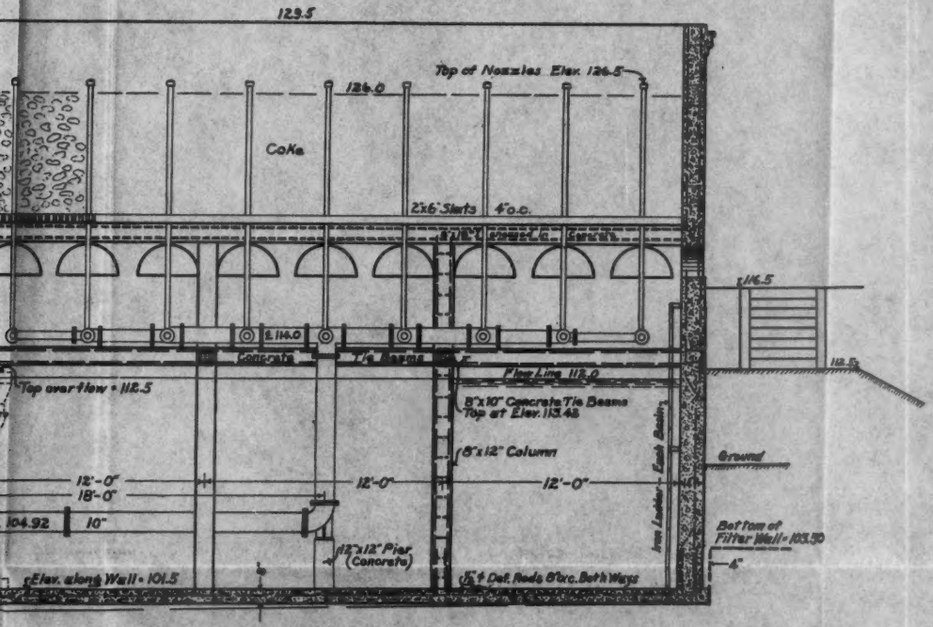
DETAILS OF AERATORS, TRICKLERS AND

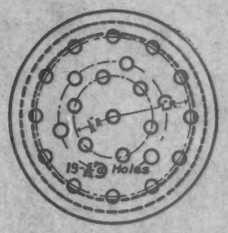
PLATE II.
N. E. W. W. ASSOCIATION.
VOL. XLII.
SAMPSON ON
AMESBURY
IRON-REMOVAL PLANT.



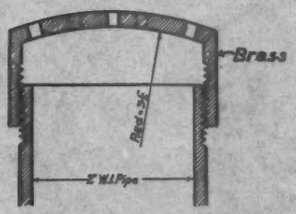


Sectional Elevation on B-B



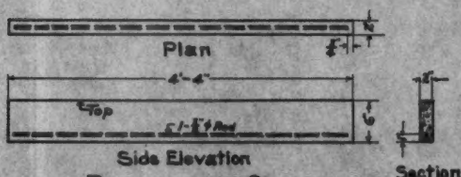


Plan



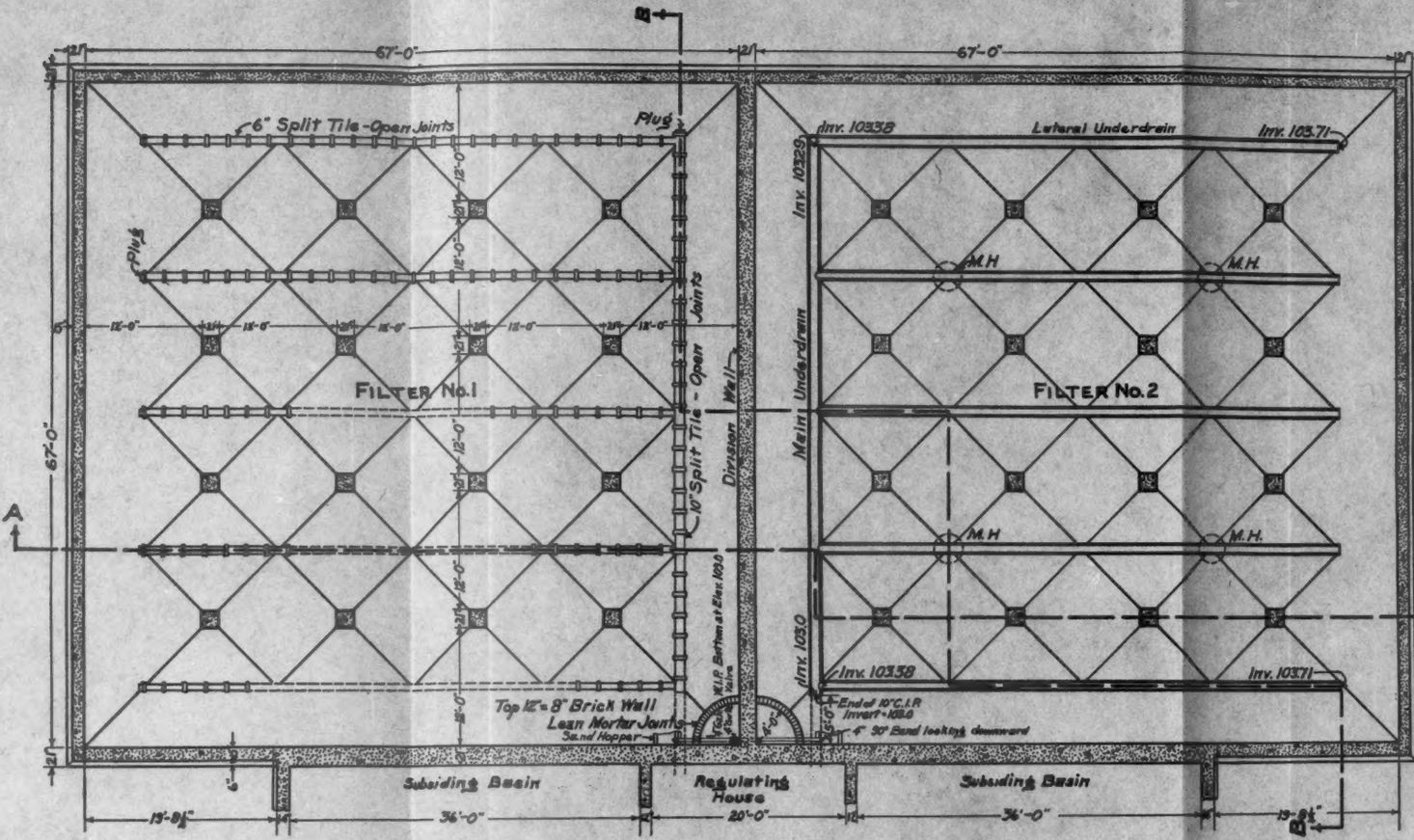
Sectional Elevation

AERATOR NOZZLES
Full Size

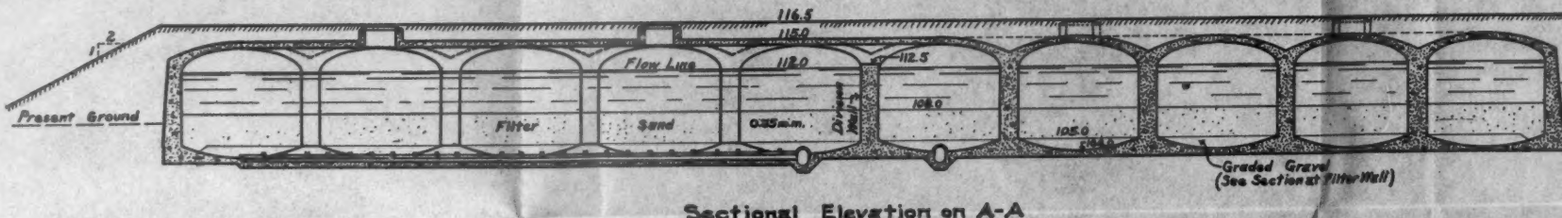


DETAIL OF SLATS

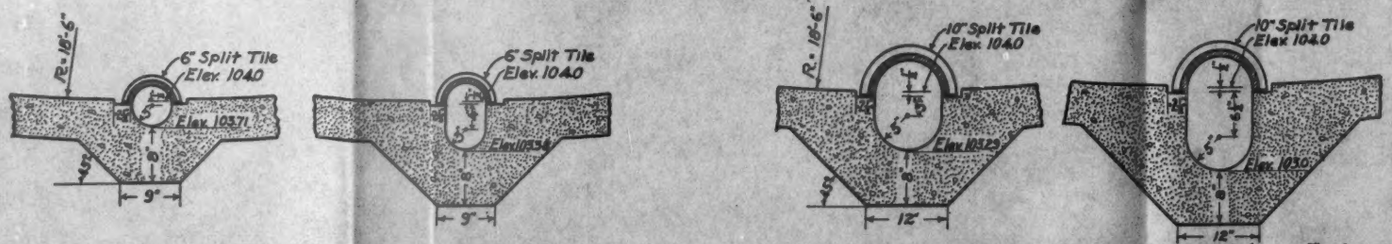
RS AND SUBSIDING BASINS, AMESBURY, MASS.



Plan



Sectional Elevation on A-A



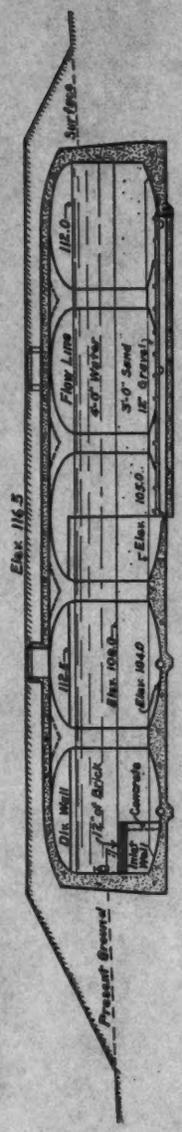
Section at Upper End — Section at Lower End

LATERAL UNDERDRAINS

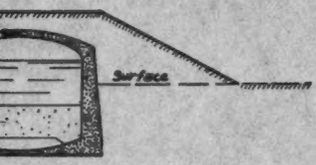
Section at Upper End — Section at Lower End

MAIN UNDERDRAINS

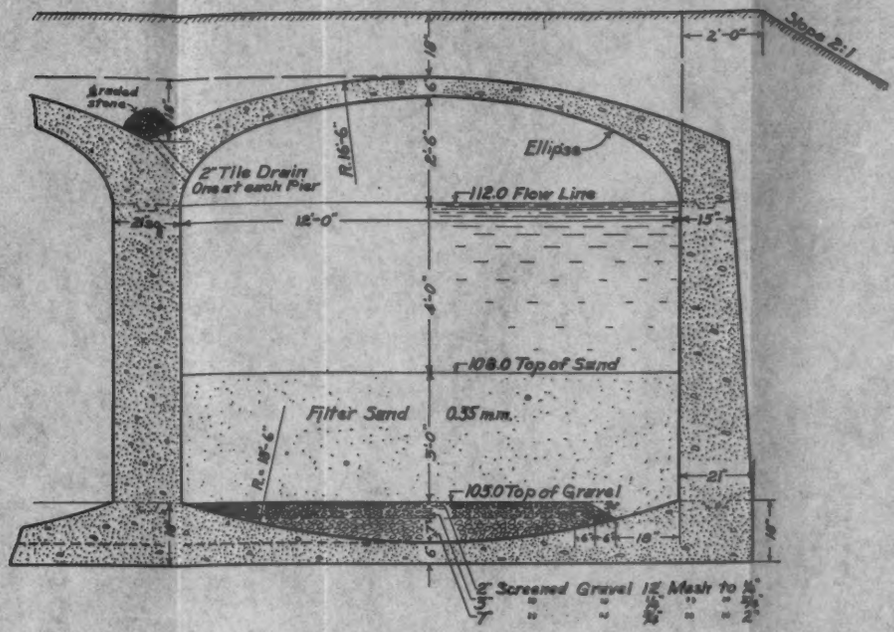
DETAILS OF SLOW SAND FILTERS, A



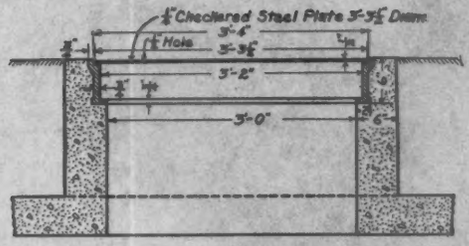
Sectional Elevation on B-B



End



SECTION AT FILTER WALL



SECTION THROUGH MANHOLE

ERS, AMESBURY, MASS.

the present normal rate of operation. The basins are connected with the filters by 10-in. piping controlled by gate valves. The details of the aërators, tricklers and subsiding basins are shown in Plate II.

Filters. There are two filter units of the slow sand type, each 67 ft. by 67 ft. in area, as shown in Plate III. The net filtering area is 8 880 sq. ft., or slightly in excess of 0.2 acre. The present normal rate of filtration is therefore about 7 500 000 gal. per acre per day. The filters are constructed of concrete without any steel reinforcement. The roofs are groined arches with a rise of 2.5 ft. and a clear span of 12.0 ft., supported on the filter walls and on 21-in. square columns. The floor is also groined with a depression of 12 in. at the center of the arches. A main collecting-channel 10 in. wide and lateral channels 6 in. wide are cast in the floor and covered with split vitrified tile laid with open joints. The main channel connects with 10-in. cast-iron filter-effluent piping extending into the filter control-house. The flow line of the filters is at the springing line of the groined arch roof, and the depth of water is 4 ft.

The filter sand is 3 ft. in depth, with an effective size of about 0.41 mm. and a uniformity coefficient of 1.5. The sand was obtained from one of the numerous sand dunes at Plum Island, and the contractor purchased two shore lots for the purpose. These lots were afterwards deeded to the town of Amesbury, so that an ample supply of excellent sand for restoring the filters is assured for many years. An allowance of 2½ in. was made for settlement, which will vary with the method of placing, and the surface of the sand was finally carefully levelled.

The filter sand is supported on screened and washed gravel stone of three sizes. The top layer, supporting the sand, is 2 in. deep, retained on a 12-mesh wire screen and passing a ¼-in. screen. The middle layer is 4 in., retained on a ¼-in. screen and passing a ¾-in. screen. The bottom layer, resting on the floor and surrounding the split tile over the underdrains, is 7 in., retained on a ¾-in. screen and passing a 2-in. screen. Each layer of stone was carefully levelled before placing the succeeding layer and especial care was used to prevent intermixing.

The roofs of the filters are covered with 12 in. of earth fill at the crown of the arches and 6 in. of loam. The depression in the roof above each column is drained into the filter through a 2-in. wrought-iron pipe with the upper end surrounded with about 1 cu. ft. of graded gravel stone. The embankments around the filter walls were placed in horizontal layers and thoroughly compacted by teaming, wetting and tamping to assist in counteracting the horizontal component of the thrust of the filter roofs. There are several 36-in. manholes in each roof for access, light and ventilation.

The final removal of the iron takes place on or near the surface of the sand in the filters. When a layer of combined iron and organic matter has accumulated to such an extent that the loss of head through the filter at the normal rate of filtration exceeds about 6 ft., it is necessary to remove this film by scraping or to thoroughly break it up by raking. The process

of scraping a filter consists of drawing down the water about two feet below the sand surface and the removal, by means of square-pointed shovels with straight, sharp edges, of as thin a layer of sand and deposit as is practicable. Usually the depth removed is from $\frac{1}{4}$ to $\frac{3}{8}$ in., and at Amesbury the total depth removed in a year, where the number of scrapings will average from 4 to 6, will be about 2 in. The process of raking a filter consists of drawing down the water, as for scraping, and carefully breaking up the accumulated mat by means of short-tooth iron rakes. The raking, which is less expensive than scraping and not wasteful of sand, will prolong the filter run from 4 to 6 weeks, and should be considered in the operation of an iron-removal plant.

The scrapings from the filters are wheeled to a hopper on the filter wall by barrows on temporary plank runs and sluiced into a sand-collecting sump below the filters with water from the other filter. This method of sand removal has several advantages over elevating the scrapings through the manholes. For large filters the sand may be advantageously removed by water ejectors and passed through sand washers for re-use. Owing to the proximity of Plum Island it is not anticipated that the sand will be washed.

Filter Control House. The piping connections with the pumping station, aërators, subsiding basins, filters and filtered-water basin pass through the pipe chamber of the filter control house and are equipped with gate valves having extension stems and gate stands mounted on the main operating floor above.

Each filter is equipped with a Simplex rate-of-flow controller having a calibrated scale-arm mounted on the operating floor, and fitted with a weight, the setting of which gives any desired uniform rate of filtration. Each filter is also provided with a recording rate-of-flow gage, with weekly charts, and an indicating loss-of-head gage.

The filter house is constructed of concrete and is provided with a chimney for heating by a coal stove, a ventilator in the roof, an iron ladder leading to the pipe chamber, electric lights, water under pressure from the street, and other accessories.

Filtered-Water Basin. The 16-in. filtered-water main runs into the pumping station where it is connected to the suction of the high-lift pumps and continues to the filtered-water storage basin located nearby. This arrangement was adopted to save pumping head that would have been somewhat increased through entrance, velocity and frictional losses if the filters had discharged directly into the filtered-water basin with the high-lift pumps connected to the basin by a separate suction-main.

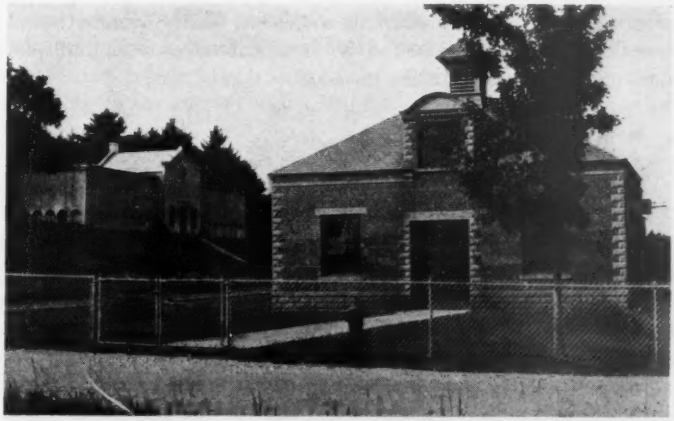
The capacity of the filtered-water basin is 250 000 gal., and for economy in construction was made of the same size and of a similar design to one of the filter units. The storage provides for an emergency supply of unpumped filtered water, especially at the time of scraping a filter, which requires about 6 hours. The flow line of the filtered-water basin is 7 ft. below the flow line of the filters and 7 ft. above the pumping-station floor.

The concrete roof is covered with 18 in. of grading and loam and the walls are backed by earth embankments.

The accompanying photograph shows a general view of the iron-removal plant. A driveway with concrete curbs and a fine crushed-stone surface, concrete steps leading to the filter-control house and to the tops of the filters and filtered-water basin, plantings of shrubbery and evergreen trees, grading and seeding with grass make for a pleasing appearance.

The total cost of the iron-removal plant, including engineering, was approximately $85 000.

Results of Operation. Treated water was first delivered to the mains on January 21, 1927, and on February 1 the iron-removal plant was placed



VIEW OF PUMPING STATION, AËRATORS AND FILTER HOUSE.

in regular operation. A marked improvement in the character of the water furnished to the town was noticed immediately upon placing the iron-removal plant in operation. Excellent results have been maintained continuously. Several analyses of the unfiltered and filtered water have been made during the past year by the writer's firm and by the State Department of Public Health. The maximum iron content of the unfiltered water was 7.50 p.p.m. and of the filtered water 0.10 p.p.m. The removal of iron averaged 98.2 per cent. and that of carbon dioxide 75.0 per cent.

The following table shows the efficiency of the treatment as indicated by chemical analyses.

	Dissolved Oxygen, Per Cent. Saturation.	Carbon Dioxide, p.p.m.	Iron, p.p.m.	pH.
Raw water	5.5	18.0	5.0	6.6
Aërator Effluent	58.4	16.0	5.0	6.8
Trickler Effluent	107.6	10.0	1.6	7.4
Subsiding Basin Effluent	109.5	6.2	1.5	7.4
Filter Effluent	105.1	4.5	0.09	7.2

On a very hot day in July, 1927, the temperature remained constant at 12° C., or 53.6° F., throughout the treatment.

The annual additional cost of operating the iron-removal plant, excluding the cost of low-lift pumping against an added head of 28.5 ft., will vary from $800 to $1 200 per year on the basis of present consumption, or about $3.50 per million gal. of water delivered to the town.

Additional Driven Wells.

The urgent necessity of providing more water was accomplished by extending the existing driven-well system. Contract drawings and specifications were prepared and on July 29, 1926, the following proposals were received and opened. The amounts are based on the summation of the engineers' estimated quantities for the various items of work multiplied by the unit prices submitted in the proposals.

Bidder.	Amount.
A	$14 816.20
B	23 778.85
C	26 349.25

The contract was awarded to Edward F. Hughes, the lowest bidder. Construction work was begun early in August and continued during the year until forty new wells were placed in service, which relieved the shortage of water. The work was suspended during the winter and completed in the early summer of 1927. Clay, quicksand and water were encountered in the excavation for the suction-main and connections of the last five wells, and although only a small amount of clay ran into the pipes in laying, it was enough to completely seal the surface of both filters in a few hours after the wells were placed in use, requiring the filters to be scraped immediately.

The additional driven-well system consists of 1 370 ft. of 12-in. suction-main, 343 ft. of 8-in. and 570 ft. of 6-in., averaging about 5 ft. in depth. Forty-seven 2½-in. wells have been installed, ranging in depth from 25 to 55 ft. The wells are of extra-heavy genuine wrought-iron pipe, sunk into a vein of sand only two to four feet in thickness but sufficiently coarse to obviate the need of strainers. The lower end of the wells is open and the bottom piece drilled with 60 ⅜-in. holes. The wells are carried several inches above the ground and capped.

The 2½-in. connection with the mains is made by a long-sweep tee, extra-heavy genuine wrought-iron nipple with cup end, lead gooseneck with soldered sweat-joints, cast-iron flange union with adjoining nipples, air-tested iron body, bronze-trimmed gate valve with bolted gland, 2-in. square operating-nut and gate box extending to the surface, connecting nipple and special bell-end casting at the main with boss at 45 degrees and 2½-in. tap. Twenty-six additional special castings were set in the mains for additional future wells.

The safe dry-weather yield of each well varies from 7 to 15 g.p.m. and probably averages 11, thereby increasing the supply of ground water by at least 750 000 gal. per day. There is an unusual underground-ledge divide between the old and new driven-well areas which distinctly separates the two sources, so that pumping from one area hardly affects the level of the ground water in the other area. When the additional wells were placed in service the vacuum at the pumping station dropped from 25 to 16 in. of mercury and the rate of pumping increased from about 800 000 gal. per day to over 900 000 with the same triplex pump in operation.

Just before the new system was put into use, each well cap was removed and a solution of chloride of lime applied, 12 oz. in all, equalling about 2 p.p.m. of chlorine for the contents of the mains and wells. The treated water was wasted through a blow-off near the pumping station for 45 minutes before being delivered to the town. Bacteriological analyses of samples taken at intervals showed a considerable benefit from the treatment, although the system was by no means completely sterilized by this method.

The total cost of the additional driven-well system, including land, engineering, etc., was about $25 000.

Pumping Equipment.

The operation of the iron-removal plant required low-lift pumping of the unfiltered water from the driven-well system to the aërators, and high-lift pumping of the filtered water from the filtered-water storage basin to the distribution system. As the existing triplex pumping-units could not be advantageously used for either service, it was decided to install entirely new pumping equipment. Contract plans and specifications were prepared and the following proposals, after being reduced to a common basis for comparison, were received and opened on August 16, 1926.

Bidder.	Amount.	Bidder.	Amount.
A	$16 817	E	$19 363
B	17 280	F	21 161
C	17 387	G	21 934
D	18 688		

The contract was awarded to Starkweather and Broadhurst, the lowest bidder, for the sum of $16 737. The work included furnishing and installing the new pumping units, all piping connections, switchboard, electric wiring, pump and motor foundations, painting and appurtenances, ready for operation. The air system was installed as an extra under the contract.

Low-Lift Pump. On account of the occasional high suction-lift from the driven wells and a considerable quantity of air with the water, it was decided that a centrifugal pump could readily be troublesome to operate.

The low-lift pump selected was a 15-in. x 15-in. Deane vertical triplex single-acting pump, having a capacity of 1.5 m.g.d. when operating at 32 r.p.m. The capacity may be increased to 2.0 m.g.d. at any later date by changing the speed to 42 r.p.m. The pump is driven by a 30-h.p., 860-r.p.m. General Electric slip-ring motor, ample for the larger capacity. A Pullmax drive with leather belt and a single-reduction helical gear give unusually quiet operation. The suction-lift at the level of the pumping-station floor averages about 22 ft. and the discharge head 28.5 ft. A 5-in. automatic by-pass is connected between the discharge and suction and a 4-in. relief valve is installed on the discharge piping to protect the pump against a closed discharge-valve.

High-Lift Pumps. The conditions of service for the high-lift pumps, with usually a head on the suction and a very constant discharge-pressure, seemed to be ideal for centrifugal units. The two pumps installed are Morris 8-in. horizontal bronze-fitted centrifugal pumps, mounted on a cast-iron base and direct-connected through a flexible coupling to 75 h.p. Westinghouse slip-ring, 1 760–1 800 r.p.m. 40-degree motors. The capacity of each pump is 1.5 m.g.d. against a dynamic pumping-head of 181 ft. The capacity may be increased to 2.0 m.g.d. against approximately the same pumping head by changing the impellers, and as the motors were actually wound on a 100-h.p. frame they are ample for this larger capacity. The higher rate of pumping would naturally increase the pumping head but this change will not be made until the present force-main has been supplemented by a second main connecting with the low-service reservoir by another route.

The pumps are so connected and valved that they may draw water from the filters directly or from the filtered-water storage-basin and may discharge into the distribution system either singly or together. The piping connections also provide for operation in series by discharging one pump into the suction of the other pump, thus increasing the discharge pressure of the second pump to about 340 ft. at a rate of 1 150 g.p.m., in case one pump alone will not supply adequate fire-service against the high-pressure reservoir. One pump alone will deliver at the rate of about 600 000 gal. per day to the fire reservoir.

The former Deane triplex pump is so connected that it may draw unfiltered water from the driven-well system and discharge either to the filtration plant or into the distribution system. It may also draw filtered water directly from the filters or from the filtered-water storage-basin and discharge into the distribution system. This pump is equipped with a 75-h.p. motor and is capable of pumping against the fire pressure when the high-service reservoir is used.

All piping is cast iron, Class "B", and all gate valves are outside screw-and yoke-valves with rising bronze stems and gate stands.

In attempting to compute the pumping head for the centrifugal pumps it was discovered that the station Venturi-meter registered 33 and 36 per

cent. in excess of the full displacement of the Deane and Rumsey triplex pumps. It was found that iron tubercles had accumulated in the tube just beyond the brass throat to such an extent that the opening was reduced to about 3 in., giving an artificial velocity and discharge. Later on, a 4-in. hard-rubber valve from one of the triplex pumps became lodged in the throat when the centrifugal pumps were started. When all obstructions had been removed, the Venturi meter was calibrated with the quantity of water actually pumped from the filtered-water storage-basin, as measured with a hook gage, and found to agree within 1.0 g.p.m. When the Venturi meter was first found to be out of order pitometer readings were taken in the force main to determine the actual rate of discharge of the triplex pumps.

Switchboard. The electric current is 2 200 volts, 3-phase, 60-cycle, alternating, but the air-pump motors are operated at 550 volts by means of an outside transformer. The switchboard and control equipment was furnished by the Westinghouse Electric & Manufacturing Company. There is an automatic, oil circuit-breaker with inverse, time-limit overload mounted on the wall and three single-pole, disconnecting knife-switches between the oil-break switch and the power lines.

The switchboard is erected on pipe supports with one panel for each motor equipped with a magnetic, automatic controller, start-and-stop, push-button station, overload and low-voltage release, disconnecting-switch, bus bars, wiring, etc. An indicating voltmeter is mounted on the board and two indicating wattmeters, one for the low-lift and the other for the high-lift pumps. There is also a reverse-phase relay to prevent the motors operating in the wrong direction, and a diaphragm-type pressure-regulator connected with the suction-main of the high-lift pumps to stop them when the water in the filtered-water storage-basin has reached a predetermined low level.

All wiring to the switchboard and motors is lead-covered cable in pipe conduits, embedded in the concrete floor.

A heavy wire-grill extends from each end of the switchboard to the wall of the pumping station, and a rubber mat is placed along the front of the board.

Air Priming System. A complete, automatic vacuum-system was installed for priming the low-lift pump and removing the air from the air chamber. The equipment consists of two No. 2 Nash rotary vacuum pumps, direct-connected to 5-h.p., 860-r.p.m., 550-volt Westinghouse motors; a steel vacuum-tank, 36 in. in diameter by 72 in. long, suspended from the ceiling of the pumping-station addition and connected with the air chamber and vacuum pumps; switchboard; automatic, adjustable vacuum switch, start-and-stop push-button stations and other electrical control apparatus; water under pressure for sealing the air pumps; drain piping and other appurtenances. The air pumps are arranged to operate

singly or in parallel with a vacuum of about 21 in. of mercury, and in series, thereby increasing the vacuum to 25 in.

The cost of the complete pumping equipment, including engineering, was about $25 000.

Addition to Pumping Station. To provide for the new pumping equipment, a brick addition 18 ft. by 37 ft. 4 in. was constructed in the rear to harmonize with the existing structure. The contract was awarded on August 5, 1926, to Earl W. Currier of Amesbury, the lowest bidder, for the sum of $2 874.00. Other changes and improvements were made in and around the pumping station, including pipe galleries, a suspended ceiling on metal lath, electric lighting, painting, grading, seeding, etc. The total cost of these improvements, including engineering, was about $7 500.

The total expenditure by the town for the complete work was approximately $142 500, and these improvements were accomplished not only with money derived from the income of the water department, but also without any increase in water rates.

Perley A. Sanborn, a member of this Association, is Superintendent of the Water Department, Thomas F. Dorsey was Construction Engineer and Joseph E. Theriault, Resident Engineer.

CLARIFICATION OF THE CATSKILL WATER SUPPLY OF THE CITY OF NEW YORK BY COAGULATION AND SEDIMENTATION.

BY WM. W. BRUSH.*

[*Read September 16, 1927.*]

Introductory. The Catskill water-supply system was brought into general use for the city of New York early in 1917, and for nearly ten years the water as delivered to the city was low enough in turbidity to make clarification treatment unnecessary. In December, 1926, a combination of very low storage reservoir level, with a flood-flow run-off, raised the turbidity to such an extent that alum and soda ash treatment was instituted and continued for nearly six months. The method of introduction of the alum and soda ash, and the subsequent removal of the alum and turbidity are of interest because of the plan followed, the results secured, and the very large volume of water treated. A very brief description of the main subdivisions of the Catskill System will be given as an aid in following the story of the treatment of the water.

The Catskill System. Two watersheds in the Catskill mountains supply the water for the Catskill System. Both these areas contain numerous steep clay banks, which are eroded when flood-flow occurs, and for periods of a few hours or days raise the turbidity from a normal value of below 5 p.p.m. to several hundred p.p.m. The Schoharie Creek watershed contains 314 sq. miles, and its flow is collected in a 20 000 million gal. reservoir from which the water is delivered through an 18-mile tunnel into Esopus Creek. This tunnel has a capacity of about 650 m.g.d. The Esopus watershed has an area of 257 sq. miles, and delivers its yield into Ashokan Reservoir, which has a storage capacity of 130 500 million gal. Ashokan Reservoir is divided into two basins known as the west and east basins, and having storage capacities of 48 300 million gal. and 82 200 million gal., respectively. Virtually all the water that reaches the east basin must first pass through the west basin. A single aqueduct 75 miles long and with a capacity of 630 m.g.d. delivers the water to Kensico Reservoir (Fig. 1), which has an available capacity of 30 000 million gal. and a total content of about 38 000 million gal. The shape of this reservoir is such that the storage capacity between the points of inflow and outflow is about 8 000 million gal., and the distance about two and one half miles. The estimated time required for the water to pass through Kensico Reservoir is two weeks. After the water leaves Kensico Reservoir it travels in an aqueduct about 14 miles before it reaches the city line. The Hillview distribution or equalizing reservoir, of 900 million gal. capacity, is just north of the city line.

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From this reservoir a tunnel delivers the water to the city mains, with the farther terminus of the tunnel at Shaft 23 in Brooklyn, 17 miles from Hillview. When the Catskill System was constructed, land was secured for a filter plant to be located between Kensico and Hillview reservoirs, but this plant was not built. At Pleasantville, three miles upstream from Kensico Reservoir, an alum-treatment plant was built so that alum could be introduced at this point and sedimentation take place in Kensico Reservoir.

Conditions that Caused High Turbidity. The Gilboa Dam, which impounds the Schoharie Reservoir, was first available for storage of water in July, 1926. On November 15–16, the heaviest run-off recorded in over twenty years was caused by a rainfall that averaged 3.63 in. in the Schoharie, and 4.37 in. in the Esopus watershed and was probably about 10 in. at points along the divide between the two watersheds where the clay banks are most numerous. At the time of the storm Schoharie Reservoir was practically empty and the Esopus Reservoir storage was 18 847 million gal. This was virtually the lowest point recorded since before 1917, when the Catskill System was first used. Schoharie Reservoir raised 52 ft., in one day, representing a gain in contents of 11 220 million gal., and in three days the contents of the west basin of Ashokan Reservoir increased from 12 059 million gal. to 28 701 million gal. The water was brick red in color and showed a turbidity of about 120 p.p.m. The draft was changed to the east basin where the water was clear, but by December 8 this clear water was exhausted and, simultaneously, turbid water began to flow over into the east basin. Under these conditions turbid water had to be delivered into the aqueduct.

Condition of the Turbid Water. Laboratory tests of the turbid water showed the following turbidities:

	Turbidity in p.p.m.
Water when collected	100
Water standing 1 to 2 days	80
Water standing 3 to 4 days	40
Water standing 5 to 16 days	20

When turbid water filled Ashokan Reservoir on previous occasions the maximum turbidity was about 30 p.p.m., which was reduced to below 10 p.p.m., before the water was drawn from the reservoir, the latter figure being the maximum turbidity at which it has been considered reasonable to deliver water to the consumer. Water with a turbidity of 10 p.p.m. could be used by passing it through Kensico Reservoir. A microscopic examination of the water showed that the clay particles were about one-half the size of bacteria, the diameters varying from about 0.0002 to 0.001 m.m. According to a table* in "The Manual of Water Works Practice" particles of this size would take from two days to about two hundred days to settle one foot. The particles were in constant motion, probably a manifestation of "Brownian Movement."

*Page 158.

It was evident that the water in Ashokan Reservoir in December, 1926, would not clarify by sedimentation for several months and that coagulation treatment would be necessary.

Treatment of the Water. Laboratory tests indicated that with a grain of alum per gallon a satisfactory floc was obtained, and the turbidity re-

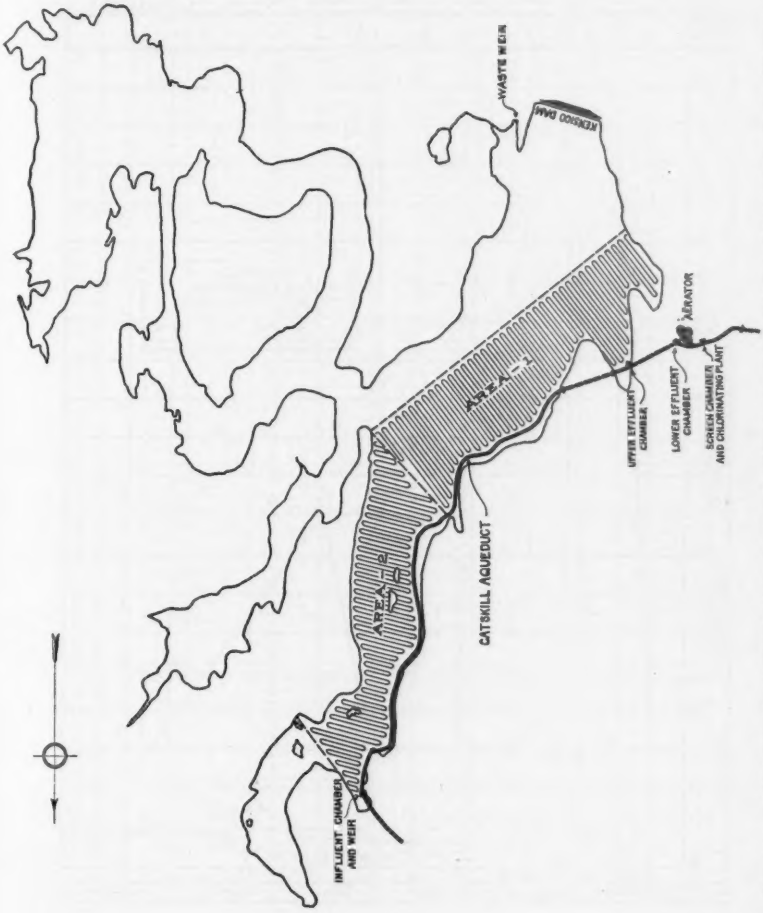

FIG. 1. — OUTLINE OF KENSICO RESERVOIR SHOWING PROBABLE AREA OF MOVEMENT OF WATER THROUGH THE RESERVOIR.

duced from 100 to about 1 p.p.m. in twenty-four hours. It was decided to treat with this amount of alum and to continuously feed the alum into the aqueduct at Pleasantville. Revolving drums had been provided to aid in dissolving the alum, but it was found that without using the drums a small pile of alum formed on the bottom of the aqueduct and thereafter the amount fed in dissolved and mixed satisfactorily with the water before it

reached Kensico Reservoir. Daily samples were taken at the point of inflow, allowed to stand for twenty-four hours, and if a clear water was obtained the result was considered satisfactory. At varying intervals of

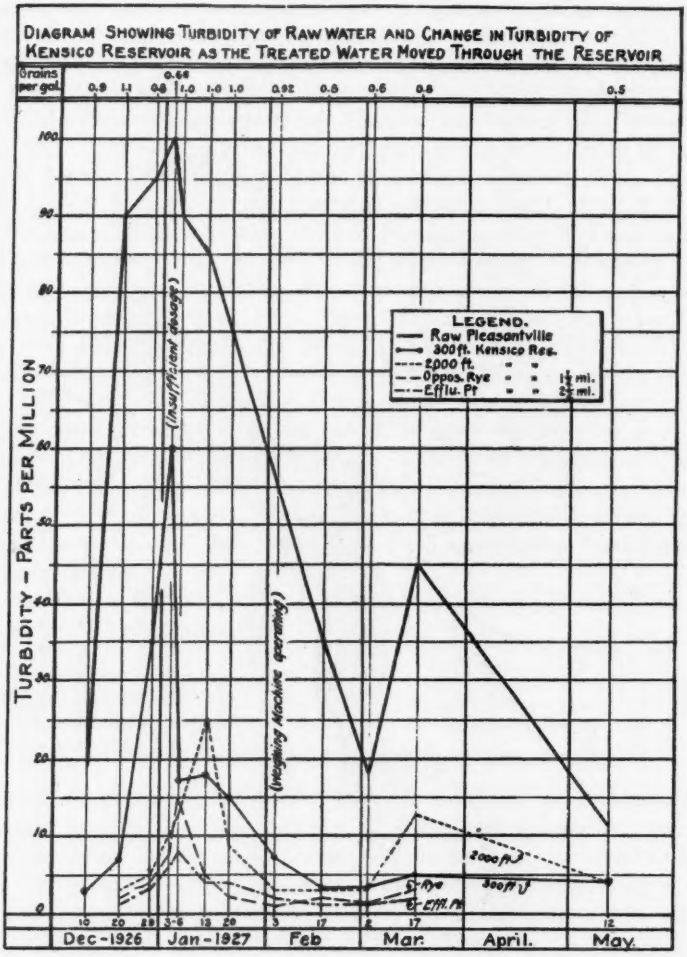

FIG. 2.

time, but averaging about once a week, samples were taken of the water in Kensico Reservoir at points 300 ft., 2 000 ft., and 1½ miles from the point of inflow and at the outflow chamber. (See Fig. 2.)

Results of Treatment. The maximum turbidities recorded were as follows:

Date.	Point of Sampling.	Turbidity in p.p m.
Jan. 3.	Pleasantville, before treatment	100
Jan. 3.	300 ft. from inflow into Kensico Reservoir	60
Jan. 13.	2 000 ft. from inflow into Kensico Reservoir	25
Jan. 6.	7 900 ft. from inflow into Kensico Reservoir	15
Jan. 6.	At efflux 13 000 ft. from inflow into Kensico Reservoir	8
Jan. 14, 25 and 27.	At Shaft 23, Brooklyn	7

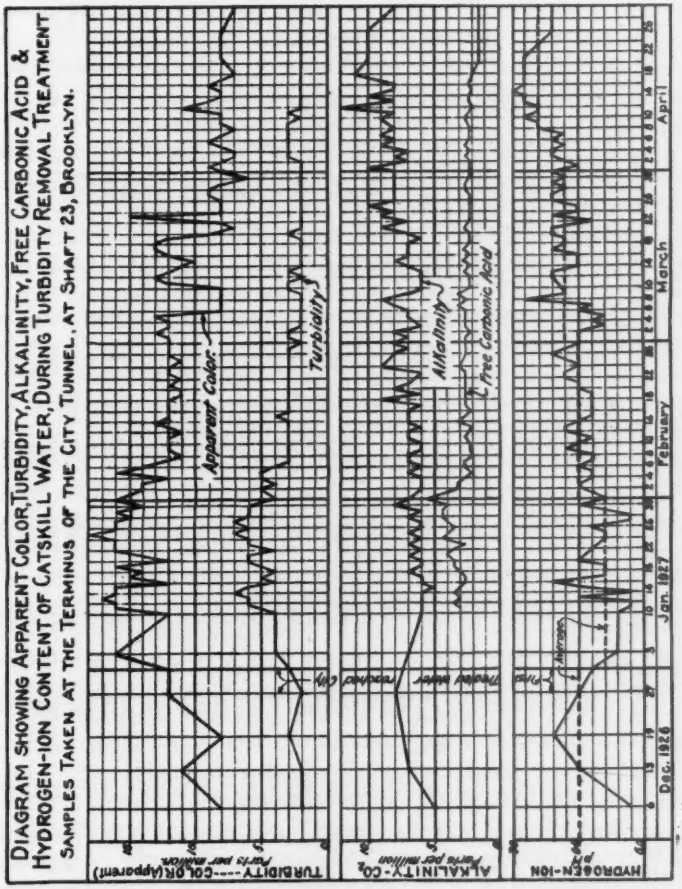
DIAGRAM SHOWING APPARENT COLOR, TURBIDITY, ALKALINITY, FREE CARBONIC ACID & HYDROGEN-ION CONTENT OF CATSKILL WATER, DURING TURBIDITY REMOVAL TREATMENT
SAMPLES TAKEN AT THE TERMINUS OF THE CITY TUNNEL, AT SHAFT 23, BROOKLYN.
Apparent Color
Turbidity
Alkalinity
Free Carbonic Acid
Dec. 1926
Jan. 1927
February
March
April

FIG. 3.

The diagram shows graphically the changes in turbidity in the raw water and in Kensico Reservoir. Early in February the turbidity had dropped to 2 p.p.m. at the effluent point, although at that time the raw water showed 55 p.p.m. at Pleasantville. In February, with a more accurate machine to record weight of alum delivered into the aqueduct, and with a turbidity below 50 p.p.m., the dose of alum was reduced to 0.9 and then to 0.8 grain

TABLE OF AVERAGE WEEKLY TEMPERATURE AND TURBIDITY OF WATER IN THE EAST AND WEST BASINS OF ASHOKAN RESERVOIR, NOVEMBER, 1926, TO JUNE, 1927.

Week Ending.	Mean depth of water in Reservoir (feet above available bottom).		Temperature — °F.						Turbidity — p.p.m. Silica.					
			West Basin.			East Basin.			West Basin.			East Basin.		
	West Basin.	East Basin.	Surface.	Middle.	Bottom.	Surface.	Middle.	Bottom.	Surface.	Middle.	Bottom.	Surface.	Middle.	Bottom.
1926														
Nov. 6	43.1	22.8	45	45	46	47	47	47	3	3	3	4	4	4
Nov. 13	43.6	23.1	44	44	44	44	44	44	6	6	5	4	4	4
20	59.5	23.1	45	45	45	44	44	45	15	30	79	5	5	10
27	78.9	19.9	42	42	42	40	40	41	66	104	120	4	3	8
Dec. 4	87.2	13.2	40	40	40	35	..*	36	100	100	100	7	..*	14
11	93.9	7.7	35	36	36	34	..	34	100	100	100	37	..	40
18	95.9	17.6	35	34	35	34	..	34	90	90	90	90	..	90
25	95.8	23.6	33	33	33	33	..	33	90	90	90	90	..	90
1927														
Jan. 1	95.6	27.6	33	33	33	33	..	33	90	90	90	90	..	90
8	86.8	37.2	34	34	34	34	..	33	82	82	84	47	..	43
15	68.8	50.2	33	33	33	32	..	33	73	73	74	37	..	40
22	58.6	54.7	33	33	34	33	..	33	36	36	38	36	..	38
29	63.9	55.0	32	32	33	32	32	32	21	25	28	27	33	34
Feb. 5	69.8	55.1	33	33	33	33	33	33	18	18	29	18	23	30
12	73.6	55.3	33	33	34	33	33	33	14	16	23	18	20	30
19	75.6	55.4	34	34	34	34	34	34	18	18	30	20	20	30
26	77.5	55.7	34	34	34	34	34	34	15	19	30	28	28	40
Mar. 5	79.6	55.9	34	34	34	34	34	34	12	16	30	30	30	41
12	81.3	55.7	34	34	34	34	34	34	14	20	30	32	32	40
19	92.0	53.8	35	35	35	35	35	35	17	28	35	30	30	37
26	96.3	60.2	36	36	36	36	36	36	33	34	40	32	32	31
Apr. 2	96.0	65.1	38	38	38	38	38	37	35	35	35	35	35	35
9	95.9	67.2	39	39	39	39	39	39	33	33	33	33	33	33
16	95.9	69.1	40	40	40	40	40	40	29	29	29	29	29	29
23	95.9	71.2	45	43	43	46	44	43	23	23	23	23	23	24
30	95.9	74.1	44	44	44	44	44	44	16	16	17	17	17	18
May 7	95.9	76.1	47	46	45	47	46	46	11	11	11	13	14	14
14	95.8	77.4	50	48	47	50	48	48	9	9	9	10	11	12
21	95.7	78.6	51	49	48	50	49	48	6	6	6	9	12	14
28	93.7	81.4	53	51	51	53	51	49	3	4	5	7	8	8
June 4	95.1	84.2	54	52	52	56	53	50	3	3	4	3	4	5
11	94.9	85.3	59	55	54	58	55	54	3	3	3	3	4	4
18	91.8	85.8	62	58	52	62	58	54	3	3	3	3	3	3
25	89.7	85.3	62	61	54	64	57	54	3	3	3	3	3	3
July 2	90.3	85.4	64	62	55	66	57	54	3	3	3	3	3	3

*Samples at middle not collected on account of shallow water.

per gallon. When the turbidity reached 20 p.p.m. the dose was reduced to 0.6 grain per gallon, and with a turbidity of about 10 p.p.m. 0.5 grain per gallon was sufficient. The treatment was stopped on May 28, 1927. The maximum treatment required about 44 tons of alum and 22 tons of soda ash per 24 hours to be fed into the aqueduct.

Use of Soda Ash. The Catskill water is very soft. It has a hardness of about 18 p.p.m. and has a high hydrogen-ion concentration, resulting in a pH of 6.3 to 6.7, thus giving a slightly acid water. The addition of the alum increased the acidity, and in the early part of January the pH fell to pH 6.1, and a noticeable increase in the complaints of "dirty water" was recorded. It had been expected that soda ash, i.e., carbonate of soda, would be added when alum was used, but none was available until December 21, 1926. The water that had been treated previously was therefore lowered in pH below normal, and increased the amount of iron oxides brought into solution from the piping system. When soda ash was secured it was added at the rate of about 0.5 grain per gallon, and the pH increased to 6.5 in February and reached 7.0 in April, as shown in Fig. 3. The soda ash was introduced into the aqueduct at Ashokan Reservoir, the proper quantity being dumped from a bag by one man at intervals of about two minutes. Tests showed that this simple method gave a thorough mixture with the water before it reached the Pleasantville plant, 75 miles away.

Record of Turbidity in Ashokan Reservoir. The turbidity of the water in Ashokan Reservoir remained high throughout the winter and early spring, and it was not until the latter part of April that the turbidity in the east basin dropped below 20 p.p.m. The very turbid water was delivered into the east basin during December and up to the middle of January. From that time until the middle of March there was practically no inflow into this basin, but the turbidity remained high, being approximately 25 p.p.m. at the end of this period. Between the middle of March and the end of May there was a substantial increase in the quantity of water stored in the reservoir, the water level rising some thirty feet during this period. The final clearing up of the water in the east basin occurred during the last two weeks in May when the turbidity dropped from approximately 12 to 4 p.p.m. The stratification of the water occurred about the middle of May and the difference in temperature between the top and bottom levels increased quite rapidly thereafter, being 4°F. on May 23, and 8°F. on May 31. It is uncertain what is the cause of the final rapid reduction in turbidity.

A table of the temperature and turbidity of the water is given in detail (see page 70) so that the record will be available for those who may wish to make use of these data in studying similar problems. The following figures give average turbidities from samples taken at the surface, middle and bottom of the reservoir in each basin:

*Samples at middle not collected on account of shallow water.

Week ending:	Turbidity in p.p.m. East Basin.	West Basin.
December 18	90	90
25	90	90
31	90	90
January 8	47 average	80
15	37 average	73
22	37 average	36
29	32 average	25
February 6	24 average	22
11	23 average	18
18	23 average	23
25	32 average	21
March 5	34 average	19
12	23 average	21
19	27	27
26	32	36
April 2	35	35
9	33	33
16	29	29
30	17	16
May 7	14	11
14	11 Stratification occurs	9
21	12	6
28	8	4
June 4	4	3

Condition of Alum Floc in Kensico Reservoir. Some question has been raised as to the condition of the alum after it settled with the clay to the bottom of Kensico Reservoir. The possibility of this material coming again into suspension in the water would be very disturbing if there were any indication of such action in the future. To date, there has been no evidence that the alum and clay will not stay permanently on the bottom. When it has been stirred up, it quickly settles again; and it would seem very unlikely that the overturning of the water due to temperature changes would move this material. It is, however, too soon to make a positive statement on this subject.

Cost of Treatment. As has been stated previously, alum treatment was commenced on December 9, 1926, and stopped on May 28, 1927. Soda-ash treatment was started on December 21, 1926, and ceased on June 3, 1927. The cost for alum treatment was:

4 635 tons of alum	$145 290	
Hauling alum from R. R. siding to plant	6 773	
Labor for handling alum at plant	5 640	
Total		$157 703
Credit from sale of alum bags		1 775
Net cost of alum treatment		$155 928

The cost for soda-ash treatment was:

2 671 tons of soda ash	$77 387	
Handling the soda ash, including unloading, hauling, storing and delivery into the aqueduct	7 900	
Total		$85 287
Credit from sale of empty bags		1 500
Net Cost		$84 787

During the period that the Catskill water was treated the consumption of water from the Catskill System was 93 243 million gal. The resultant cost per million gal. treated was, in round figures, $2.60. There are approximately 4 000 000 people who receive their water supply from the Catskill System, and the cost per person amounted to about six cents for nearly six months' treatment.

DISCUSSION.

GEORGE W. FULLER.* This paper contains much valuable information. The city of New York is fortunate in having such large reservoir capacity below the location where coagulant can be suitably applied for purposes of clarification. In this respect the conditions for the Catskill water supply are more favorable than those at St. Louis, Nashville and some other Midwest cities where available reservoirs do not serve so adequately.

One of the most significant features of the treatment of the Catskill water supply relates to corrosion which comes with this very soft water-supply and, particularly, in cold-water piping — according to my observation. Opportunities for applying chemicals to control corrosion of soft-water supplies is a matter which, I believe, will receive more attention in the future than hitherto, not only for the Catskill project but also for others.

Coagulation experiences in the clarification of the Catskill water bring up many interesting questions relating to the behavior of particles that do not settle readily. I recall that in earlier years some comment was made on the clarification of the Catskill supply in Kensico Reservoir being due to the differing physico-chemical characteristics of the Catskill water and the water entering Kensico Reservoir from the watershed of the Bronx River on which the reservoir is located. The Bronx River area shows granitic formation, in comparison with the bluestone found in the Catskills. Whether the very fine particles found in the waters coming from the two watersheds had any tendency to coalesce, thus promoting clarification, is a point that I would like to ask Mr. Brush about in the light of recent observations.

MR. BRUSH. We have never had any change in the water going through Kensico other than that due to the period of time for the water to

*Consulting Engineer, New York, N. Y.

pass through this reservoir. There has not seemed to be any change that would be attributable to the mixture of the waters which came from the local tributary watershed of Kensico and the water that came down from the Catskills. In previous years, when we have had in Ashokan Reservoir a turbidity slightly higher than we were willing to send to the consumer, we have depended upon sedimentation as the water passed through Kensico, to clarify the water. No change was observed of a nature differing from that apparently also taking place in Ashokan Reservoir in the same period of time. There was clarification, due to dilution and sedimentation, during the two or three weeks that it takes the water to pass through Kensico Reservoir.

ROBERT SPURR WESTON.* I would like to ask Mr. Brush if he could tell, within reasonable limits, what is the minimum period of storage required to obtain a reasonable degree of clarification by the treatment he has used.

MR. BRUSH. From the evidence available, based upon the treatment of last winter, a satisfactory reduction in turbidity could have been secured at a point 2 000 ft. from the inflow chamber, and this turbidity could have been from 5 to 10 p.p.m. if the dosage had been uniform and adequate. Two thousand feet represents about a two-day travel of the water in the reservoir; but I would be very much concerned if I only had two days' travel of the water I tried to treat, and I would not advocate this type of treatment under such conditions.

MR. WESTON. Did you obtain better clarification in the reservoirs than you did in bottle experiments in the laboratory?

MR. BRUSH. Clarification taking place in the reservoir has always been slower than that obtained in bottles in the laboratory. We tested, for example, the rapidity with which clarification would take place in the laboratory when we had 100 p.p.m. of turbidity in the water. Such a sample showed 20 p.p.m. turbidity still present in 5 to 10 days, and after about two months the turbidity had dropped to about 7 p.p.m. In the reservoir itself it was five months before we got down to a turbidity of 7 p.p.m. In the reservoir there was some influence on the turbidity from the inflow of the stream. A part of the time the inflow of the stream contributed a higher turbidity than 20 p.p.m.

MELVILLE C. WHIPPLE.† I was just thinking of some of the happy days I spent working on this problem in 1914. That was the year that Ashokan Reservoir was first filled, and when it filled it was very red with clay from the surrounding country and from the clay banks within the reservoir. At that time we built small basins for studying coagulation near the Ashokan basin. As I recall, we had the greatest difficulty in manufacturing turbid water from the natural products of the region there and in getting that turbidity to stay in suspension in the basins that we

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†Assistant Professor of Sanitary Chemistry, Harvard University, Cambridge, Mass.

built. The basins were shallow, perhaps two feet deep, and there was a good deal of vegetation. It was remarkable to see how quickly the turbidity would be deposited in those basins where there was grass and a good deal of muck, much quicker than it was deposited in the bottles kept in the field laboratory. I was wondering whether the spring overturn, if there was such a thing this year, had any influence in bringing organic matter or iron, or both, into circulation.

I would also be interested to know if the east basin responded to clarification in the spring any better than did the west basin, the east basin being the one that contains, I believe, the largest amount of organic matter.

MR. BRUSH. As to the overturn — there was a constant vertical movement throughout the winter. During the week ending May 14 there was the first evidence of the cessation of the vertical movement.

PROFESSOR WHIPPLE. You had no winter stagnation?

MR. BRUSH. No, we did not. We had a large volume of water coming in all the time, and the result was that we had this constant vertical movement as well as the movement caused by wind action and by the volume of water coming in. I am now basing my statement upon the temperatures observed at the surface, the middle and the bottom of the reservoirs. Of course we did not make those tests throughout the body of the reservoir. We made the test usually at or in the vicinity of the intake chamber.

The east basin did not clarify any more rapidly than did the west basin — in fact, it did not clarify as rapidly; but we had the uncertain factor of a larger dilution from the stream flow into the west basin than into the east basin. We were in hopes that by putting the water over into the east basin and leaving it quiescent that we would have more rapid clarification of the east basin. That did not occur. The water remained as highly turbid in the east basin when it was quiescent as it did in the west basin where it was not as free from movement on account of the inflow. There did not seem to be any evidence of any condition in one basin as compared with the other that had any effect on the rapidity with which sedimentation took place.

I wish somebody would give an adequate reason why quick clarification takes place when the water warms up in the spring. It may have nothing to do with the warming up of the water, and very possibly it has not, but it was at this time that quick clarification took place.

We were planning to continue our treatment during the summer and had asked for an appropriation so that we could do so, because up to about a month before final clarification took place there was no evidence that we would have clear water until the latter part of the summer.

The turbidity in Kensico Reservoir is usually about 2 p.p.m., so that you see we have normally very clear water as we deliver it to the consumer.

RICHARD G. TYLER.* I wish to enquire whether there was any evidence indicating the location and direction of the turbid currents entering

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Ashokan Reservoir. In other words, was it found that this turbid water, with its higher specific gravity resulting from suspended solids and lower temperatures (at certain seasons), moved toward the outlet along the bottom of the reservoir, or did it flow along the surface or become thoroughly diffused throughout the reservoir?

We have been carrying on some experiments on the characteristics of flow in basins, at the Massachusetts Institute of Technology. These tests have been made on models and I am not sure as to how far the laws of hydraulic similitude may be able to relate our data to full-size conditions. However, the effect of temperature differences was found to be very marked in our experiments, and it is believed that similar effects occur in reservoirs and lakes. A drop in temperature of only a few degrees was sufficient to cause the inflowing water to follow along the bottom of the basin. Since the water in the basin experienced an increase in temperature on standing at laboratory temperatures, especially with long detention periods, the incoming water was at a lower temperature and it was found necessary to hold these temperatures about the same in order to get the desired results.

I believe that this stratification is more general and more important than we have been inclined to believe and, in the case mentioned by Mr. Brush, it might cause the turbid water to reach the outlet of the reservoir very much more quickly than computations would lead one to expect. The rather abrupt clearing of the water in spring may have been assisted in various ways by the microörganisms present, and sudden or considerable changes in the flora of the water may be in part responsible for changes in the rate of clarification.

MR. BRUSH. After the storm that occurred the middle of November, presumably the inflowing water was at a lower temperature than the water in the reservoir. The water did flow along the bottom of the reservoir and was as high in turbidity as 180 or 200 p.p.m. at the bottom, immediately following the storm. I cannot say how long the high turbidity remained at the bottom, but it was only a question of a few days before we had at the lower end of the west basin the same turbidity at the bottom, middle and top. At first, the cold water flowed in at the bottom, and subsequently there was an admixture throughout the entire vertical section of the waters.

If the reservoir is full and we have a flood in the summertime, the turbidity is never as persistent as it was last winter. Sedimentation takes place quite rapidly and the water moves down as a body in the reservoir so that it is very easy to trace the line of the incoming turbid water as compared with the clear water in the basin. This storm in the fall traveled under the waters in the reservoir, which was at a very low level, and reached the intake chamber in a very short period of time as in less than a day we had the highly turbid water at that point.

ARTHUR B. MORRILL.* It has occurred to me that possibly the increase in temperature may have had some effect in causing clarification.

*Assistant Engineer of Filtration, Detroit, Mich.

I believe that I am right in saying that natural coagulation is more rapid at higher temperatures than at lower temperatures, and that sedimentation is also more rapid, due to the decreased viscosity of the water; but it seems rather odd that there would be a sufficient increase in temperature in a few days to account for it.

I would like to ask Mr. Brush whether he has continuous records of the hydrogen-ion concentration of the incoming water, and whether differences in pH could have had any effect on clarification. Hydrogen-ion concentration probably has a very important effect on coagulation and sedimentation, and there is a possibility that the incoming water could have changed enough to have had some effect on clarification.

MR. BRUSH. If increased temperature causes clarification, why is it that when the water is heated to 70° F. in the laboratory the clay remains in suspension, while when the water rises to only about 58° in the reservoir clarification is completed by sedimentation?

The hydrogen-ion concentration of the stream of water was undoubtedly higher at the time of year when clarification took place than it was at earlier periods, but when clarification did occur it took place throughout the entire reservoir, and in the east basin there was virtually no opportunity for the incoming water to mix with the water that was in the reservoir. There would seem to be at least an indication that clarification was not occasioned by mixing the turbid water with the incoming water. At that time the west basin was being drawn upon, to about the full flow of the stream. The farther part of the east basin clarified just as thoroughly and in just about the same time as the rest of the reservoir cleared up.

The hydrogen-ion concentration of the water does not vary greatly. The average pH for the year 1924 was 6.6. When we added soda ash we increased the pH to 8, and that had apparently no effect upon the rapidity with which clarification took place.

MR. MORRILL. Was there any change in the microscopic life at the time of clarification?

MR. BRUSH. Only the normal change. The microörganisms were low during the wintertime, and there was no noticeable increase or decrease. Of course we had a very large volume of water coming from the stream which was free from microörganisms as it came in. There has been no development of microörganisms this year that has caused any treatment to be necessary, but in the east basin of Ashokan we had to shut off a week or so ago on account of Synura. From a cursory examination of reports there has been no noticeable effect on microörganisms, due to the character of water that has been in the reservoir during the past eight or nine months.

MR. MORRILL. Was the alum applied at the same point as the soda ash?

MR. BRUSH. No. A distance of seventy miles intervened between

the two points. The question of the addition of soda ash has not been finally settled — as to whether, if we are to use soda ash for the purpose of preventing corrosion, we shall add it along the aqueduct or as the water enters the city tunnel. We did not carry on any experiments that are conclusive on this point; but if this coming year we are to add soda ash for the purpose of reducing corrosion, we expect to experiment on the effect of adding it to the aqueduct before the water enters Kensico Reservoir and of adding it as the water enters the city tunnel.

WHAT EVERY ENGINEER AND WATER-WORKS SUPERINTENDENT SHOULD KNOW ABOUT CHLORINATION.

BY RICHARD V. DONNELLY.*

[*Read September 14, 1927.*]

The use of chlorine for safeguarding drinking-water supplies is now almost universal in North America. Engineers and water-works operators are constantly encountering problems concerning chlorinating apparatus and practice. The purpose of this paper is to summarize, in a general way, many practicable suggestions that will materially aid in both the recommendation and operation of chlorinating equipment. An effort has been made to make the discussion apply to chlorinators and chlorination in general rather than to any special type of apparatus or process.

CHLORINE EQUIPMENT.

Chlorine is a yellowish gas and is supplied commercially in steel containers as a liquid. The pressure of the chlorine varies considerably with the temperature. Figure 1 shows the relationship between temperature and chlorine pressure. The chlorine cylinders are supplied in two sizes, one having a net weight of 100 lbs. and a gross weight of 200 lbs., the other a net weight of 150 lbs. Chlorine is also supplied in containers of one ton net weight to large users. Prices vary from approximately 5 cents a pound in large amounts to 12 cents in single containers at the factory.

The chlorine-cylinder valves are equipped with standard $\frac{3}{4}$-in. pipe-thread outlets. All chlorine manufacturers take special care to have the chlorine cylinders used for water-works purposes especially clean, and they often paint them a distinctive color. The chief chlorine manufacturing plants are at Niagara Falls, N. Y.; Wyandotte, Mich.; Pittsburg, Cal.; Windsor, Ont.; and Belle, W. Va. Chlorine is manufactured by electrolyzing brine solution, so that a combination of cheap salt and power is necessary.

All types of chlorinators, using liquid chlorine, have several common functions to perform. The liquid chlorine is gasified by reducing its pressure. This is accomplished at the valve of the cylinder itself, the discharge pressure on this valve being much lower than the pressure inside the cylinder. The gas is then conducted to the chlorine regulator. The manufacturer of chlorinating apparatus supplies a valve known as an auxiliary tank valve which is attached to the chlorine-cylinder valve (Fig. 2) by either a threaded union or by a clamp, depending on the type of cylinder valve used by the manufacturer of the chlorine. Flexible copper tubing, known

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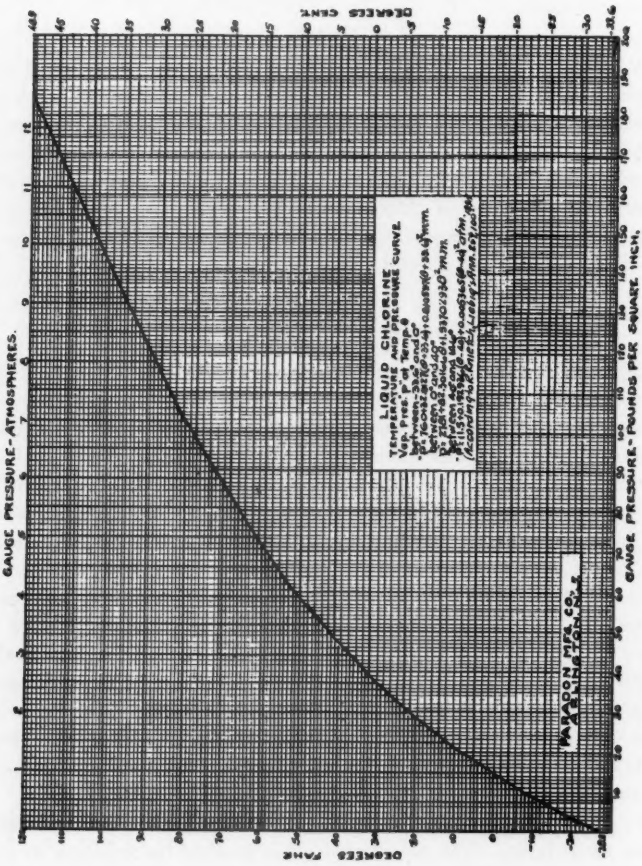
as a tank connection, is supplied by the chlorinator manufacturer and is connected from the auxiliary tank valve to the actual chlorine regulator.

The function of the chlorine regulator, regardless of type, is to —

1. Reduce the chlorine pressure.
2. Measure the flow of chlorine under this reduced pressure.



CHLORINE TEMPERATURE - PRESSURE CURVE.

FIG. 1.

3. Maintain a constant drop in pressure across a measuring orifice.
4. Maintain a constant back pressure on the measuring orifice.
5. Provide means of altering the rate of chlorine flow.

Figure 3 shows a typical regulator-unit in cross-section. The chlorine as a gas enters the gas-inlet manifold. The chlorine pressure-gage indicates the pressure in the chlorine tank. The chlorine continues through a needle valve known as the inlet valve. This reduces the gas pressure.

The inlet valve is actuated by a diaphragm. Pressing against the back of the diaphragm is a spring known as the regulator-back spring. By a rod operating through a stuffing-box, it is possible to alter the tension on this spring, increasing or decreasing the difference in pressure between the two sides of the diaphragm.

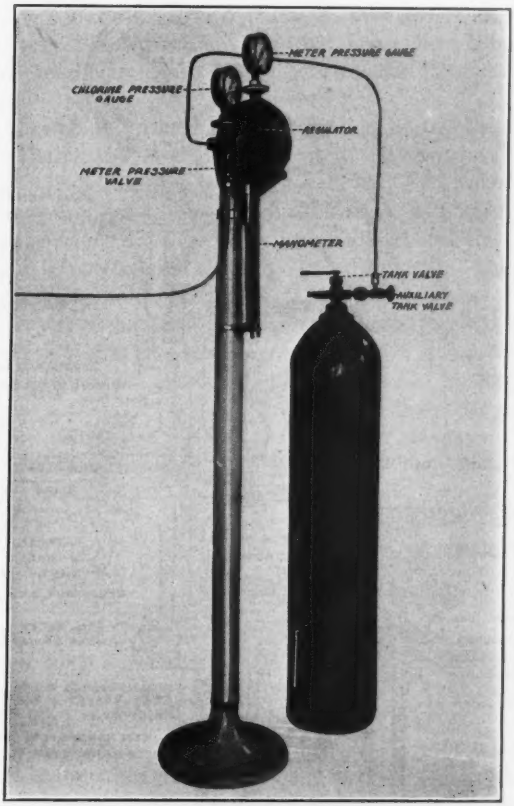


FIG. 2.— DIRECT-FEED CHLORINATOR.

From the inlet valve the chlorine, under reduced pressure, passes along the front side of the diaphragm and through an orifice. The discharge side of the orifice connects to the back of the diaphragm. Hence the drop in pressure through the orifice is always equal to the difference in pressure between the front and rear of the diaphragm and is controlled by the position of the adjustable rod which alters the spring tension.

Since the flow through an orifice is a direct function of the drop in pressure through it, it is possible, by varying the spring tension, to vary

the flow of chlorine. A manometer connects across the orifice; the outer tube connecting to the inlet, or high-pressure side, the inner tube to the outlet, or low-pressure side. Carbon tetrachloride is used to seal the end of the inner tube. When gas is flowing the difference in pressure between the inner and the outer tube causes the liquid to rise in the inner tube. A

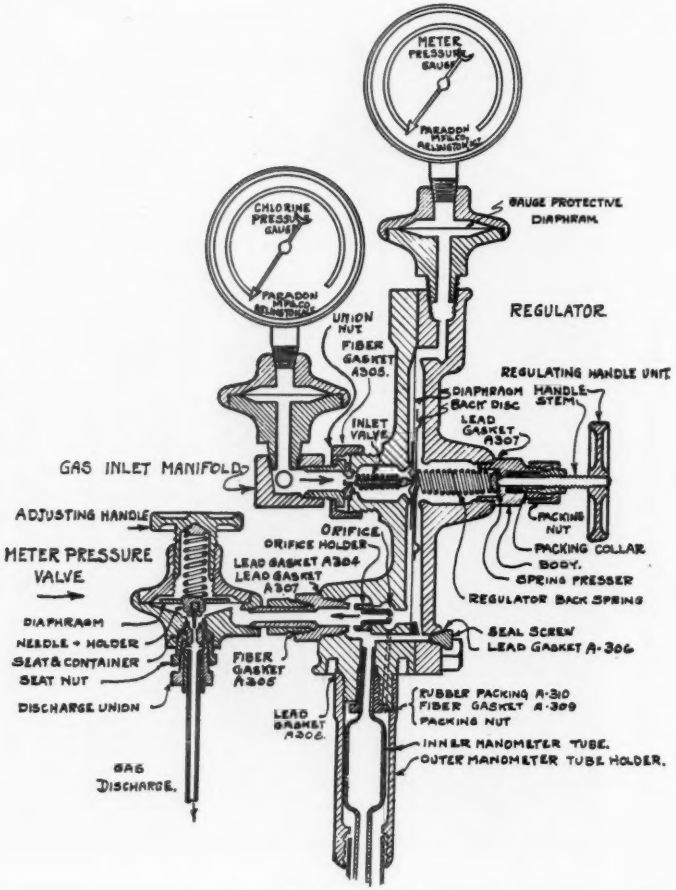


FIG. 3.— GAS CONTROL UNIT.

scale empirically calibrated for the particular orifice in pounds of chlorine per 24 hours, or other convenient unit, measures the rise of liquid in the inner tube.

From the orifice the chlorine flows through a constant-pressure device which maintains a constant back-pressure. There are several ways of accomplishing this. In the case illustrated, an adjustable spring maintains

a pressure on a needle valve, allowing this valve to open only when the chlorine pressure exceeds that of the spring. The meter pressure-gage indicates this back pressure on the orifice. It should be maintained equal to the back pressure under which the orifice was calibrated.

The drop in pressure across the orifice and, consequently, the flow of chlorine are unchanged by changes in tank pressure of the chlorine, as long as there is any liquid chlorine in the tank, because any change in tank pressure affects both sides of the diaphragm and, hence, both sides of the orifice equally, due to the by-pass passage between the front and rear of the diaphragm.

From this point onward the construction of the chlorinator is dependent on the process of chlorination used. If the so-called direct-feed process is to be used, the gas is conveyed directly by flexible silver tubing to the point of application and is applied directly as a gas by means of a diffusion device which divides the gas into small bubbles, this diffusor being usually either of perforated silver or carborundum. Figure 2 shows a typical direct-feed chlorinator.

Another type of chlorinator is the so-called solution-feed type, in which the chlorine gas is first mixed with a small flow of water, this mixture of chlorine and water then being applied to the water to be chlorinated.

In this case the chlorine gas would go from the meter pressure-valve to a device for mixing chlorine with the small flow of water. Several types of mixing-devices are available. In one of them a flow of water passes through a hard-rubber jar and chlorine is bubbled into the jar. A non-corrodible shut-off valve is provided between the hard-rubber jar and the control parts of the machine. When the machine is not in operation this valve is closed. Chlorine pressure is retained in the machine, and no moisture can, therefore, enter any part of the control device. The aspirator, or injector type of mixer, is somewhat more complicated but is particularly recommended when it is necessary to introduce chlorine solution against high pressures. A vacuum relief is provided to prevent moisture getting into the machine, due to partial vacuum formed by gradual absorption of chlorine when the machine is shut down. This vacuum relief consists of a chamber between the machine and the injector which contains a hard-rubber float. The bottom of this float is sealed by a small stream of water from the injector water supply. Should an excess of water enter this chamber the float rises and lets in air, and the vacuum is immediately broken.

From the solution mixing-device the chlorine and water are conveyed to the point of application by flexible rubber tubing.

A new type of chlorinator, known as the thermo type, employs different methods for regulating the flow of chlorine. Instead of using a pressure-reducing, constant-pressure valve of mechanical construction, the simple expedient of keeping the temperature of the chlorine constant is resorted to. The standard chlorine cylinder is immersed in a water bath, which keeps

its temperature practically constant and with it also the pressure. The flow of chlorine is controlled by a needle valve and is measured by means of a volumetric bubbling- or pulsating-meter. The actual bubbles of chlorine are counted, each bubble being equal to a certain weight of chlorine. The chlorine solution is then drawn into an injector. This machine is only made in solution-feed injector-type form, as the suction pull of the injector is necessary for its operation, this suction being used to seal and unseal the glass cylinder in which the measuring meter bubbles. When the injector is in operation the cylinder is filled with water by the suction created; when the injector stops operation the cylinder unseals and prevents any water or moisture being drawn back into the control valve. A small part of the injector water-supply is also necessary to keep the water bath in operation.

A similar machine is equipped to use a special 12-lb. cylinder of chlorine for very small installations.

A brief description has been given of several common types of machines and of two chlorination processes. A few suggestions will be made as to what particular type machine the engineer or water-plant operator should recommend for any particular conditions.

Dr. F. E. Hale, Chemist of the Department of Water Supply, Gas and Electricity, New York City, as long ago as 1914 determined that, in so far as bacterial efficiency was concerned, the results obtained from the direct application of chlorine and the so-called solution-feed type were the same. The mechanical features of the apparatus are also equally satisfactory. In fact, many types of chlorinators are identical in every respect, both for solution feed and direct feed, except that the injector is inserted in the former case. The main points to be considered are the engineering features of the particular installation.

A solution-feed apparatus requires a water supply under at least 20 lbs. per sq. in. pressure. There must be approximately 50 gal. of water available for each pound of chlorine used. The pressure at the point of application should not be more than one-third the pressure of the water supply available to operate the machine.

A direct-feed apparatus does not require any water supply. The pressure in the chlorine cylinders with direct-feed apparatus is sufficient to overcome pressures at the point of application up to 25 or 30 lbs. per sq. in.

If direct feed is applied into an open body of water, the diffusor must be submerged sufficiently to prevent gas escaping to the surface. The depth of submergence varies with the flow of water at the point of application. A submergence of 4 ft. is usually sufficient. Generally the factor of prime importance is the rate of water-flow past the diffusors.

Direct-feed installations are generally more simple to operate and install and are somewhat less expensive.

The special adaptabilities of the two types can best be illustrated by several examples.

Case 1. A gravity water supply; desired point of chlorine application at the reservoir. This clearly calls for the direct-feed type since no water pressure is available for operating the solution-feed type.

Case 2. The same gravity water supply; reservoir inaccessible; desired point of application on the outskirts of town before the first tap; pressure at this point 50 lbs. per sq. in. In this case a solution-feed chlorinator would be desirable, since 30 lbs. per sq. in. pressure is the maximum safe pressure against which the gas can be applied directly. However, to use solution feed would require a booster pump to supply the injector with a pressure at least three times that at the point of application, or a pressure of 150 lbs. at the injector.

Case 3. A pumped water supply; suction pressure 10 lbs. per sq. in.; discharge pressure 25 lbs. A direct-feed apparatus would fit best here since the gas pressure itself could be used to overcome the 10 lbs. per sq. in. pressure in the suction line, while if solution feed were used, it would be necessary to install a booster pump, as in Case 2, in order to get the three-to-one pressure-ratio.

Case 4. A gravity filter plant; water flows by gravity to the filters and then by gravity to the town. A small pump is used for wash water. A direct-feed chlorinator would apply here since there is no water under pressure available.

Case 5. The same as Case 4, except that a tower is used to supply wash water. Either direct or solution feed could be used in this instance but direct feed would probably be preferable, since the tower and pump were intended only for wash water, and it might be an item of some cost or annoyance to supply additional water under pressure, especially if the chlorination system be a large one.

In a great many cases, probably the majority, either solution or direct-feed can be used with equally good results, and some local consideration determines the choice.

The author's experience with some 600 units indicates that, in general, there is no difference whatsoever in favor of one or the other method in the case of water chlorination.

Specifying Equipment.

In writing chlorinator specifications or making recommendations it is well to consider several important requirements common to both solution- and direct-feed equipment.

The chlorinating apparatus must be properly protected from the elements. The temperature of the apparatus should be kept at 45° F. or above. There is not much danger of a chlorinator freezing, but when low temperatures are reached the pressure of the chlorine itself becomes so low that improper operation often results.

One can safely draw at a rate of 50 lbs. of chlorine per day per cylinder. If one draws more, the evaporation is so fast that the cylinder tends to freeze

(unless it is artificially heated). Thus if one is handling 300 lbs. of chlorine a day one should have at least six cylinders and provide connections and auxiliary tank-valves for them.

The usual chlorinator orifice has a range of five maximum to one minimum. Thus, an orifice of 50-lbs. maximum capacity will have a minimum capacity of 10 lbs. Within certain limits the capacity of a machine can be altered merely by changing the orifice. With several types of machines with which the author is familiar these ranges are as follows:

No. 1 — 1 to 75 lbs. of chlorine per day.
No. 2 — 75 to 150 lbs. of chlorine per day.
No. 3 — 150 to 300 lbs. of chlorine per day.
No. 4 — 300 to 500 lbs. of chlorine per day.

Thus No. 1 machine could be converted to any capacity on a five-to-one range up to 75 lbs. per day merely by inserting the proper orifice and scale, say, 5 to 25 lbs.; 10 to 50 lbs.; 12 to 60 lbs. However, above 75 lbs. it will be necessary to enlarge several other parts of the machine.

Locate the chlorinator so that the temperature of the cylinders is never higher than that of the chlorinator; otherwise the chlorine gas is liable to reliquefy in the apparatus. This causes irregular operation and often causes deposits which tend to clog up the unit.

The chlorinator manufacturer usually supplies everything from the chlorine cylinder to the point of application. Be sure that you provide for an initial supply of chlorine.

It is desirable to specify that supervision of installation be made under the direction of the manufacturer. A chlorinator is simple to install, but it is something out of the ordinary, and often an installation gets started badly, merely because some simple point was overlooked, due to unfamiliarity with the equipment.

Exercise care in specifying the chlorine capacity. Chlorine dosages in the United States range all the way from one pound to 7 or 8 lbs. per million gal. of water in extreme cases. A good average dosage is 3½ lbs. per million gal. Just how much chlorine will be required is very difficult to estimate. It varies at different seasons. It is best to be over-cautious and have sufficient maximum capacity. This can ordinarily be secured by specifying an extra orifice and scale. These orifices and scales can be changed in a few minutes. Thus, for example, if the maximum flow was two m.g.d., an average chlorine dosage would call for a capacity of 7.0 lbs. of chlorine per day. A 2–10 lb. orifice would take care of ordinary requirements. An additional orifice having a range of 4–20 lbs. could be specified. This would provide for any possible maximum dosage. Have the meter in use of such capacity that the average chlorine consumption requires one-half to three-quarters the maximum capacity of the meter rather than the minimum capacity. This greatly facilitates reading the

scale. The scale is logarithmic and, at the minimum flows, a division has several times the value that it has at maximum flows, making it very much easier to read the scale and to adjust the rate when the flow is at or near maximum.

There are several so-called extras that, while not absolutely necessary, are to be desired with a chlorinator installation.

Platform scales are relatively inexpensive, and are very useful in determining when cylinders are empty and in checking up the chlorine consumption over periods of time. The beam of these scales should be silver-plated. The platform should be of sufficient size to take care of the number of cylinders required for the particular installation. Direct-reading scales are also occasionally supplied. The scale can be made a part of the chlorinator, if desired.

A chlorine-testing outfit should be provided. Several state health departments have already requested the chlorinator manufacturers to supply a testing outfit as part of the equipment of every machine shipped into their respective States. The ortho-tolidin test is the simplest one and is in most general use. It is a color test and can be made by almost anyone. Every chlorinator should be operated in conjunction with frequent tests for available chlorine.

It is desirable to provide for the chlorinator a separate gas-tight room, well vented to the atmosphere. This keeps the machine out of the way and prevents its being tampered with.

The chlorine tubing, either silver or rubber, should be protected at all exposed places.

If possible, chlorinators should be installed in duplicate. It is better to arrange for continuous operation at half load for both machines, since a chlorinator operates best when in constant operation. If it is impossible to provide a duplicate installation, a liberal supply of spare parts should be provided. The manufacturer should be consulted for the extra parts to be recommended with the particular type of machine.

Common Troubles with Chlorinators.

Some common troubles experienced with chlorinators can also be appropriately included in this discussion.

It is the author's opinion, based on many years of observation with many types of chlorinators, that 90 per cent. of all troubles are due to lack of proper knowledge on the part of the operator rather than to any inherent fault of the chlorinator itself. The installation man of the manufacturer may be careless in instructing the operator, operators may change, or the apparatus may be installed wrongly.

After all, a chlorinator is a comparatively simple piece of equipment. It has practically no moving parts. Most of its operation is based on hydraulic rather than mechanical principles. There are many more compli-

cated pieces of equipment about a water-works plant. Given the proper care a chlorinator should last for years and give practically no trouble. Neglected, it may not last a year.

Chlorine is extremely corrosive when moist. Very few materials will withstand it. Possibly the greatest cause of deterioration in chlorine apparatus is leakage of chlorine. All leaks should be stopped at once, no matter how minute. If a water pipe leaks slightly, the rust will often stop the leak. A slight leak of chlorine combines with the moisture in the air and starts corrosion which in a day or two may corrode the apparatus and any other metal object nearby very badly. The slightest amount of chlorine forms dense white fumes with ammonia, and hence a leak is readily located. Keep plenty of gaskets on hand.

Keep moisture out of the machine. If you break a connection, plug it up. If you take any fittings of the machine apart, clean them with wood alcohol, carbon tetrachloride or similar agent before reassembling.

Don't allow the machine to flood. Manufacturers provide various means to prevent this under ordinary conditions, such as the vacuum-relief or chlorine-shut-off valve, previously mentioned. Flooding often occurs when the machine is shut down. There is a small amount of chlorine left in the apparatus. Moisture has access to the machine at the point of application. This moisture gradually absorbs the residual chlorine, a partial vacuum is formed and water is drawn into the apparatus. If the vacuum-relief and back-pressure valve do not prevent this access of moisture, break the connection at the point of chlorine application so that this vacuum cannot form. If water does get into the machine, take the apparatus apart and dry thoroughly with wood alcohol.

Another source of trouble is stoppage of the various connections and ports. Several of these ports must of necessity be relatively small on account of the small amount of chlorine required for water purification. A slight amount of impurity, either in the chlorine gas itself, or perhaps in the machine, due to corrosion, may stop up one of these passages. Don't be afraid to trace the path of the chlorine right from its entrance into the machine to the point of application. The two pressure-gages are of help in this connection. A print showing the construction of the machine should be procured. Make a systematic inspection and locate and clean the stopped-up passage. This is very important.

The inlet valve, regardless of the type of chlorinator, is the first point to be inspected. The latest types of machines, including the ones previously described, are designed so that this inlet valve is immediately accessible. The orifice occasionally clogs; also the two passages leading into the inner and outer manometer tubes. On rare occasions the tank connections clog; in fact, practically every part should be systematically examined in this connection. Often a machine will clog up a few days after cleaning; this means there are some impurities in the chlorine. If there is dirt in the chlorine cylinder, return the gas for credit; don't continue to use it. It is

advisable to blow off the chlorine cylinders for a few seconds into the atmosphere before connecting to the apparatus.

Get complete prints of the machine. Learn its construction and do not be afraid of it. Keep the metal parts of the machine well greased; this prevents their becoming discolored and their corroding; in fact, keep the machine neat and polished up. The only reason for the white vitrified enamel finish on the chlorinators in common use is to enable them to be kept looking neat and to give the operator an incentive to give them good care. This means long life.

With solution-feed machines of the injector-feed type trouble has sometimes been encountered with the injector. It may suddenly stop drawing-in the chlorine. This may be due to falling-off in water pressure, due to a clogged injector strainer, or to an extra demand on the water-supply line. It may be due to increased back pressure on the injector discharge, due, for example, to the kinking of the discharge hose; or the throat of the injector may have become clogged.

Chlorine hydrate forms in certain types of solution-feed chlorinators. It forms in cold concentrated chlorine solutions, at temperatures about 40° F. To eliminate formation of chlorine hydrate, heat the water used for operating the machine. The temperature of the room in which the chlorinator is housed has nothing to do with the formation of the hydrate. To heat the water, one type of chlorinator is provided with an electric heater; steam coils can also be used. Chlorine hydrate also tends to form on the carborundum type of direct-feed diffusor. The author's experience shows that the silver diffusor tends to eliminate this particular trouble.

New Uses of Chlorine.

Many new uses of chlorine in the water-works field have recently come to the fore, and these will be touched upon briefly and in a very general way.

Chlorine is now being used successfully at several places for the control of algæ. In a filter plant the raw water may be prechlorinated. This tends to eliminate algæ growths on the filters and in the underdrains and helps to eliminate taste, odors and other troubles due to algæ. One or two places have recently tried chlorinating the surface of reservoirs for algæ control. A dozen or more outdoor swimming pools have successfully eliminated algæ growths entirely by the use of chlorine.

Several power plants in England and, to the author's knowledge, two or three in the United States, have prevented deposits on condenser tubes by chlorination. It is well known that chlorination prevents the growth of *Crenothrix*. Chlorine has been used successfully to eliminate tastes and odors already imparted to a water supply by algæ. Chlorine appears to be practically effective on algæ that are not readily destroyed by copper sulphate.

It is yet too early to predict to what extent chlorine will be used for

algæ removal, but recent results seem to indicate that its value in this field has heretofore been underestimated. No accurate study of dosages is available. A residual chlorine of 5 p.p.m. appears to be the usual dosage at this time.

Howard, at Toronto, has successfully used, on a large scale, super-chlorination followed by de-chlorination with sulphur dioxide. To secure proper bacterial removal at certain seasons of the year requires a high chlorine dosage. The excess is neutralized with sulphur dioxide gas. This practice has been followed in England for several years. Howard is said to maintain a slight excess of sulphur dioxide and to use the ortho-tolidin test for his control. At Rahway, N. J., super-chlorination is neutralized by aëration.

Ammonia and chlorine are being used both in England and in the United States to prevent chloro-phenol tastes. At Greenville, Tenn., liquid ammonia is used to make up an ammonia-water solution which is added to the raw water. Chlorine is added to the filtered water.

Double chlorination is coming into practice rather extensively. First, regardless of its purpose, it has the advantage of practically eliminating any interruption in chlorination. It may be used not only for algæ control, but with certain waters may also materially aid coagulation. Alum consumption may be decreased not only by better coagulation but by improved filtration due to elimination of algæ in the bed and underdrains.

Newly laid water mains are often sterilized with chlorine just before putting them into use. Sections of existing mains may also be chlorinated if pollution is suspected.

Watersheds upon which construction activities are in progress may be protected by emergency chlorination of all water discharged onto the catchment area, or by the chlorinating of streams receiving this discharge.

Seattle, Wash., in addition to regular chlorination on the pipe lines leading to the city, has used a chlorinating boat to sterilize water in Lake Young, particularly at areas near the entrance of several of the tributary streams. Buffalo, N. Y., has used a portable chlorinator to sterilize the filters and clear-water basins of the water-purification plant. Chlorine is used in several Florida cities to remove sulphur tastes from the water supplies.

Chlorine is being used with increasing frequency in the disinfection of sewage. The dosage ranges, on the average, from 5 to 15 p.p.m. The cheapness of chlorine in large amounts, 5 cents delivered at the present time, is, of course, a big factor in promoting its use in sewage treatment. Major developments in the sewage field may be expected within the next few years.

In conclusion, the author feels safe in saying that chlorine is perhaps the most useful chemical at the disposal of the water-works engineer. Its cost is relatively low. Its field of usefulness is capable of large expansion. Latest developments in its application should be carefully followed.

THE WEATHER-MAP STORY OF THE FLOODING RAINSTORM OF NEW ENGLAND AND ADJOINING REGIONS, NOVEMBER 3–4, 1927.

BY J. HENRY WEBER* AND CHARLES F. BROOKS.*

[*Read January 11, 1928.*]

Three factors joined to make the extraordinary rainstorm in New England, November 3–4, 1927 — according to a weather-map study. The first factor was a large supply of damp tropical air that happened to be on tap over the Gulf Stream and the Atlantic southward. It was marked by low pressure on the weather maps for a few days preceding the flood. The second factor was the piling-up of a great and almost immovable mass of air in the East, from Maine, Nova Scotia and Newfoundland eastward. This was marked by high pressure on the maps. The third factor was the southward flow of a considerable body of cold air into northern New England and along the Appalachian ranges and through their valleys to the Middle Atlantic coast. After three days of northward flow of the tropical air, funneled into western New England between the air masses on the east and on the west, such great masses of damp air were forced together and up over the obstructing mountains and their northern and western higher bulwarks of cold air — while at the same time they were being overturned by the cold air above — that unprecedented quantities of water fell in a short time.

The rainfall in southern New England and New York east of the Hudson River averaged about five inches, and locally amounted to over nine inches. Vermont's downpour averaged not less than seven inches for the entire State. The average fall in New Hampshire was about five inches and that in Maine three inches or slightly less, ranging from under an inch on the coast at Portland to over four inches to the northwest. The heaviest rains occurred along the length of the Green Mountains, where the mountain wall and the cold air to the west forced the greatest ascent of the warm air; and in a belt from Westerly, R. I., to Groton, Mass., the path of a small low-pressure center within the general storm. The main storm center moved northward up the Connecticut Valley and was attended by high southerly and southeasterly winds and gales on its east side. The development and movement of this storm was clearly shown by the four-hourly weather maps constructed from data received from U. S. Weather Bureau and Canadian weather service stations, also from ships at sea.

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How the Stage Was Set.

The tropical contribution to the New England flood began early in October, during which month three heavy rainstorms, largely of tropical origin, soaked New England. A week before the flood the barometer was relatively low in the middle and eastern Caribbean, and on the evening of October 28 a disturbance of slight intensity passed over Santa Lucia, in the Windward Islands, advancing apparently west or northwestward. Havana reported nearly 12 in. (11.86) of rainfall for the 24-hour period ending at 8 A.M. on the 29th. On the 30th and 31st the barometer continued low south and southeast of Cuba. On November 1 the barometer was low over southern Florida, Cuba and the Bahamas, with the lowest pressure, 29.78 in., over central Cuba. The morning of the 2nd a tropical low-pressure area, apparently of slight intensity, was noted just east of the Bahamas, moving north-northwestward. Other meteorological conditions were extremely favorable for the northward movement of great masses of tropical air and, in consequence, for the further development of this general tropical low-pressure area and its expansion over the eastern seaboard.

During the last few days of October the pressure distribution on the continent of North America favored strong southerly winds in the Middle West. In consequence, great volumes of warm, moist air were transported from the Gulf of Mexico far northward into Canada. The Atlantic coast and the Appalachian region, however, experienced clear and moderately cool weather with northerly winds, attending the southeastward advance of an area of higher pressure from Canada. It was this high that later formed the central and southern portion of the air wall over the western Atlantic that helped drive northward the enormous flow of tropical air that passed over New England early in November.

By October 31, there was a temporary reaction to colder weather in the lower Missouri and the upper Mississippi valleys, but the temperatures continued unseasonably warm in most of the Lake region and in the Ohio Valley, while the remainder of the eastern United States showed a reëstablishment of seasonal or abnormal warmth. Some stations in the Ohio Valley and the Lake region reported temperatures equalling or exceeding the record for so late in the season, some readings being as high as 80° F. The warm weather overspread the Atlantic States by November 1. Over the East the movement of air from a tropical quarter continued unabated through the 2nd. An area of lower barometer in the Mississippi Valley moved rapidly northeastward. On the morning of the 2nd a sharp trough of low pressure, marked by nocturnal thunderstorms, extended from its center, southeast of Hudson Bay, south and southwestward to Texas. This marked the dividing line between the considerably cooler temperatures on the west and the abnormal warmth on the east. Boston, with a maximum of 76° F., had the temperature equal to the highest for November ever recorded in the history of the local station. This low-pressure area

was a secondary of the Pacific low that appeared in the western Aleutian Islands October 19 and entered North America, October 28. The primary center was at this time over Baffin Bay. This energetic secondary moved northward to the mouth of Hudson Bay.

Moderately heavy rains occurred in northern New York and Vermont during the night of November 2nd as the cold front of the storm area passed northeastward between Hudson Bay and the St. Lawrence River. The temperature began to fall incident to its passage and by 8 P.M. the 2nd the readings were in the forties, or below, west of a line northeastward from Tennessee through the Ohio Valley and western New York to Montreal. On the east, far north, to the mouth of the St. Lawrence River, the temperatures of the southerly winds were in the neighborhood of 60° F. or higher. The barometer had fallen along the Atlantic coast, due to the eastward movement of a mass of air of lighter density in connection with the northern storm and, subsequently, owing to the great inflow of tropical air from the ocean.

The Weather-Map Story in Detail.

During the following twelve hours the tropical low-pressure area and the southern end of the trough from the northern low increased considerably in extent and exerted their influence over the entire Atlantic coastal region. In order to obtain a comprehensive understanding of its movement, intensity, and the meteorological conditions in the area influenced by this storm, special maps have been constructed. (Figs. 1–6.) These maps show the weather conditions beginning at 8 A.M. on the 3rd and ending at 8 P.M. the 4th. Reports of weather conditions were obtained with the cordial assistance of the Boston office of the U. S. Weather Bureau, Mr. G. A. Loveland, official in charge, for all United States stations and for many Canadian stations east of the 80th meridian, as well as ship reports from the western Atlantic Ocean. Special reports for this period were also received from private observatories at Amherst and Worcester, Mass., and from Brattleboro, Vt.

Figure 1 shows that at 8 A.M. November 3 the barometer readings were about 29.6 in. in the Carolinas and eastern Virginia, with low pressures extending far out to sea; while another low center, the tropical disturbance, was now apparently near latitude 30 north and longitude 74 degrees west.

The cold, dense air had made little progress eastward, except in the northern portion of the St. Lawrence Valley. The Appalachian Mountains marked, in general, the boundary line between the cooler, drier air to the westward and the very warm, humid air to the eastward. In New England the cold air had advanced to the crest of the Green Mountains and the Berkshire Hills, the east-west gradient in temperature being unusually steep. At Albany at 8 A.M. the thermometer read 44° F., while at Amherst, Mass., it stood at 63° F. — a difference of 19° in 70 miles. At Concord,

N. H., and at Brattleboro, Vt., the temperature was 60° F., while at Northfield, Vt., the mercury was 42° — a difference of 18° in 80 miles.

With an immense wall of dense air to the northeastward, where the barometer reading was as high as 30.4 in. at Cape Race, Newfoundland, and above 30.6 in. over the ocean to the east, and a cold wall of air to the

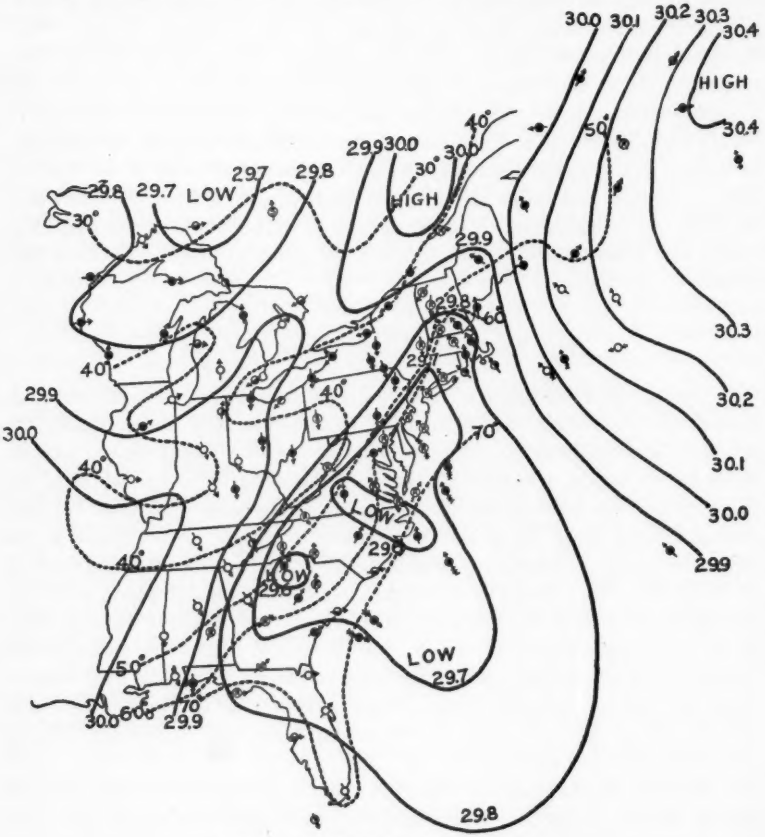

FIG. 1.— NOVEMBER 3, 1927.— 8 A.M.

west and northwestward, the south Atlantic storm area was as if caught in a vise by its meteorological enemies. The path of least resistance was northward along the coast and thence inland into New England. The pressure distribution already indicated this, for there was a narrow pointer of lower pressure extending northward to southern Vermont, while there was a looping of the isobars from there north-northeastward to the St. Lawrence River, indicating perhaps a greater northward movement of the tropical air there than elsewhere on the east or west.

The great, moisture-bearing tropical current was of considerable depth, as is indicated not only by the northward movement of the low-pressure area but also by cloud drifts. For example, observations at Worcester, Mass., showed an inflow of air from the southeast or south to a height of at least two miles, where alto-cumulus clouds, the highest visible during the storm, were moving from the south. Aërological observations at Boston showed a south-southeast or south wind up to 9 800 ft., the highest observation. At this height the wind was blowing at a speed of 45 miles per hour from the south; at the 6 500-ft. level the velocity was 51 miles per hour from the south-southeast. A movement of upper clouds from the south was also observed at Washington, D. C.

Over the Atlantic coastal region and to some distance eastward over the ocean the air was warm and muggy and, consequently, greatly expanded, while from the Appalachians westward, the air was cold, dry, and therefore much denser. The stage was now set for the torrential rains that began in the district between the Hudson and the Connecticut rivers by noon that day, and in the remainder of New England, except eastern Maine, by 8 P.M. that night.

Let us now discuss briefly the physical causes of these heavy rains. The main cause of excessive precipitation is the elevation of large masses of warm, humid air, by convection or instability overturning, by forced ascent, over a topographical barrier or even over a barrier of cold, dense air, or by convergence of strong winds. All the above factors appear to have been instrumental in producing the heavy rainfall in New England. No wonder the rain fell in torrents!

The Green Mountains and the Berkshire Hills have an average elevation of from 1 500 to 3 000 ft. West of these, and across northern Vermont and New Hampshire, cold air was banked up to heights probably exceeding those of the mountains. The strong southeasterly winds, bringing in great masses of vapor to heights of at least two miles, were, upon reaching this combined mountain and air barrier, forced to rise and were therefore expanded, greatly cooled and compelled to yield large quantities of rain. If we assume a barrier only 3 500 ft. in height the saturated air on rising would be cooled by expansion, offset by latent heat, approximately 10° F. Furthermore, since the cold, dense air was moving south and southeastward and the warm, light air northwestward, there was a convergence of these air masses, violent upthrusts, with instability overturning above, and additional cooling; all these factors producing an aggregate cooling of at least 15 to 20° F. Saturated air when cooled 18° F. has its so-called capacity for holding moisture reduced by about one-half. Since, very likely, the cooling in this case was approximately equal to or greater than that amount, we can easily see why the rain fell in torrents along and to some distance east and west of the line of greatest upthrust of the warm, muggy air. As the meteorological conditions, mentioned previously, did not change materially during the subsequent 24 hours, it is not difficult to

conceive of the recorded 6 to nearly 10 in. of rain falling in the Berkshire Hills, the Green Mountains, and in the adjoining regions. More than a cubic mile of water fell on the State of Vermont. For the precipitation of such a vast quantity of rain a mass of warm, damp air, equivalent to a current

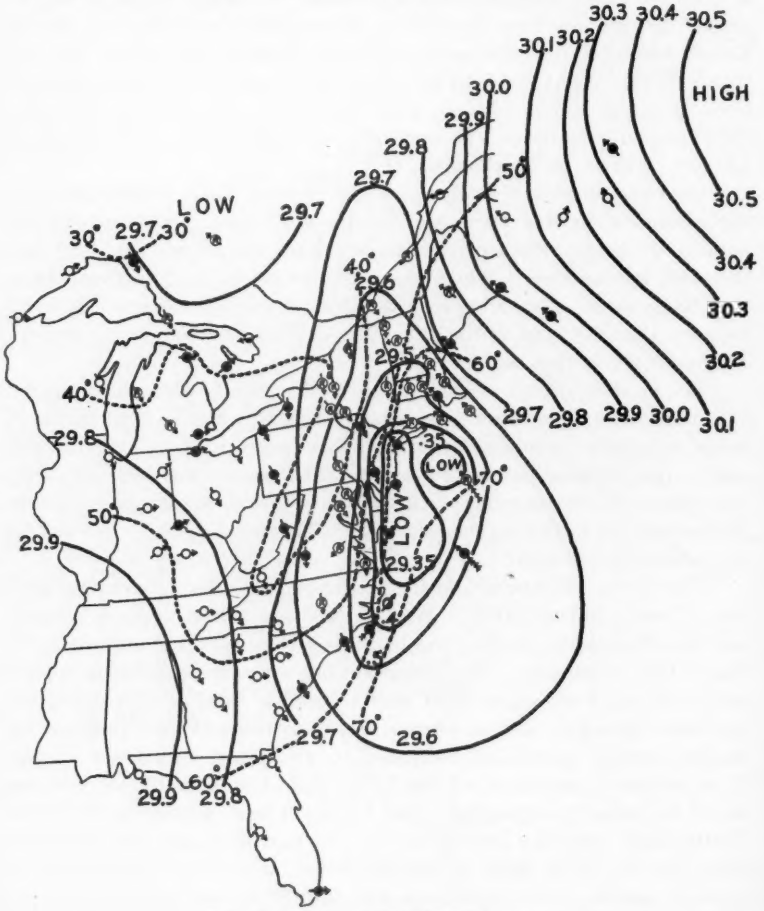

FIG. 2.— NOVEMBER 3, 1927.— 8 P.M.

two miles deep and covering four or five times the area of Vermont, must have passed over the State and ascended two miles while doing so.

During the 12 hours following 8 A.M. of November 3 the tropical air continued its rapid flow northward, but there was little change in the position of the front of cold, dense air to the west and northeastward. At noon the barometer had fallen along the Atlantic seaboard from Florida

to Nova Scotia. The pressure readings were in the neighborhood of 29.55 in. from North Carolina to Long Island, with one center of slightly lower pressure over central Virginia and North Carolina, a second off the coast of Virginia, and a third, the tropical low (not shown on the maps) farther

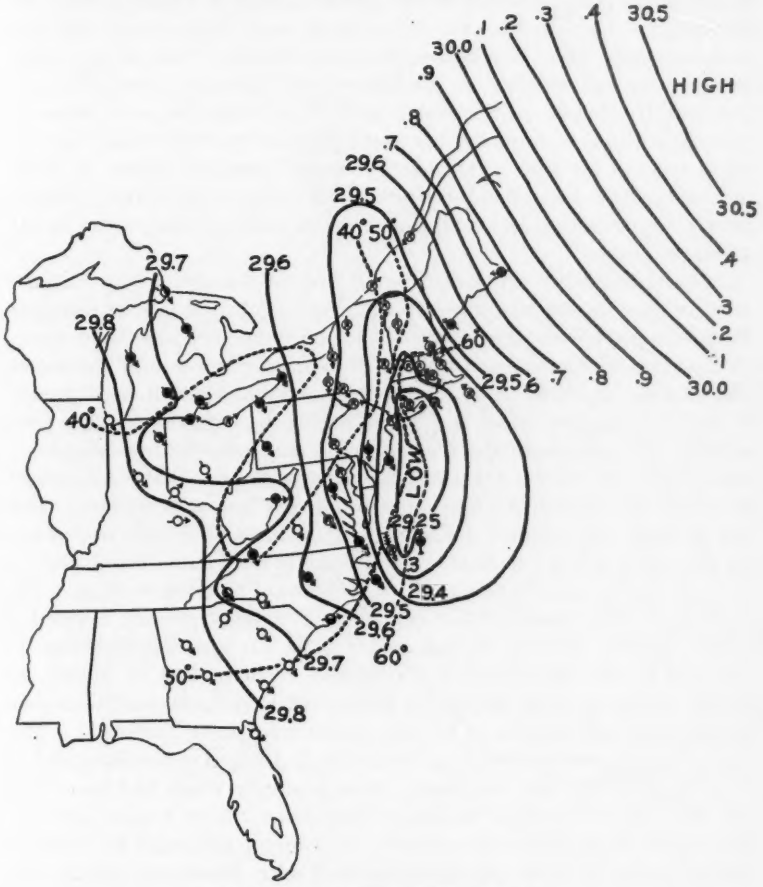

FIG. 3.— NOVEMBER 3, 1927.— 12 P.M.

out to sea. Ships to the east and southeast of the center near the coast reported southeast winds of force 6 to 9.

By 4 P.M. the two coastal centers noted at noon had apparently combined into one well-defined storm area. It now appeared as an oblong low, extending from North Carolina to Long Island, Atlantic City reporting the lowest pressure, 29.38 in. The 8 P.M. map (Fig. 2) shows that the center of the low was along the coast of New Jersey, Atlantic City and New York,

both having a barometer reading of 29.33 in., while a few ship reports indicate a second low of similar intensity, possibly the tropical low, south of New England. This map, like the three previous ones, shows a conspicuous wedge of lighter air, or lower pressure, extending from the southern New England coast to the central portion of Vermont and New Hampshire. By midnight (Fig. 3) the storm center was south of the New England coast where the pressure was below 29.25 in. The narrow wedge of lighter air still extended up the Connecticut Valley to central Vermont and New Hampshire; to the west it seemed as though the cold, dense air were attempting to push its way eastward through this wedge, but the warm tropical air with inexhaustible reserves speeding rapidly in from the southeastward repulsed the sallies of its meteorological foes. Twelve more hours were to pass before this territory was to be evacuated by the southern invader.

By midnight it is probable that the low, noted south of New England at 8 P.M., had moved inland from the Rhode Island coast, and at midnight it was centered between Providence, R. I., and Worcester, Mass. (not shown on the maps because of small scale). At Worcester the reduced barometer was 29.4 in., or .06 to .10 in. higher than at Providence, R. I., Concord, N. H., and Amherst, Mass., and .02 in. higher than at Boston. The wind at Providence was blowing at a velocity of 50 miles per hour from the southeast while at Worcester it was north 8 miles per hour. Between midnight and 1 A.M. the rain fell at a rate of nearly 2 in. per hour at Worcester. This low pressure, one of small diameter, was undoubtedly largely responsible for the excess of 3 to 5 in. that brought totals of from more than 9 down to 6 in. of rainfall from Westerly, R. I., northward to Groton, Mass. The greatest rainfall intensity in Vermont, and possibly western Massachusetts, occurred between 11 A.M. and 8 P.M., but especially between 11 A.M. and 5 P.M., November 3. Northfield reported 4.24 in. during the former period and 3.20 during the latter. In Burlington, conditions were similar, although the rate of fall was not as great as at Northfield. This heavy rainfall occurred before general rains had begun in the remainder of New England, for then the warm, moist southerly winds had been dried but little before reaching the Green Mountains. After 8 P.M., however, the humid air gave up an abundance of moisture in the region to the south and southeast, so that upon reaching the Green Mountains this air had already been considerably dried. In consequence, the rate of fall in western Massachusetts and Vermont could not be so excessive as during the previous period, although the rate could still be classified as heavy.

Figure 4 shows that by 4 A.M., November 4, the center of the disturbance had moved inland into the Connecticut Valley, althouth the barometer was still falling. The lowest barometer readings were 29.08 in. at Amherst, Mass., and 29.09 at Hartford, Conn. The small disturbance over central Massachusetts had now apparently merged with the main storm. A slight northern disturbance, noticed north of Lake Superior at

8 A.M. of the 3rd, had moved farther eastward. This low-pressure area had practically joined the storm from the south by midnight, November 3, though showing as a separate center to the north at 4 A.M. the 4th, Montreal having a barometer reading of 29.26 in., lower than any of the near-by

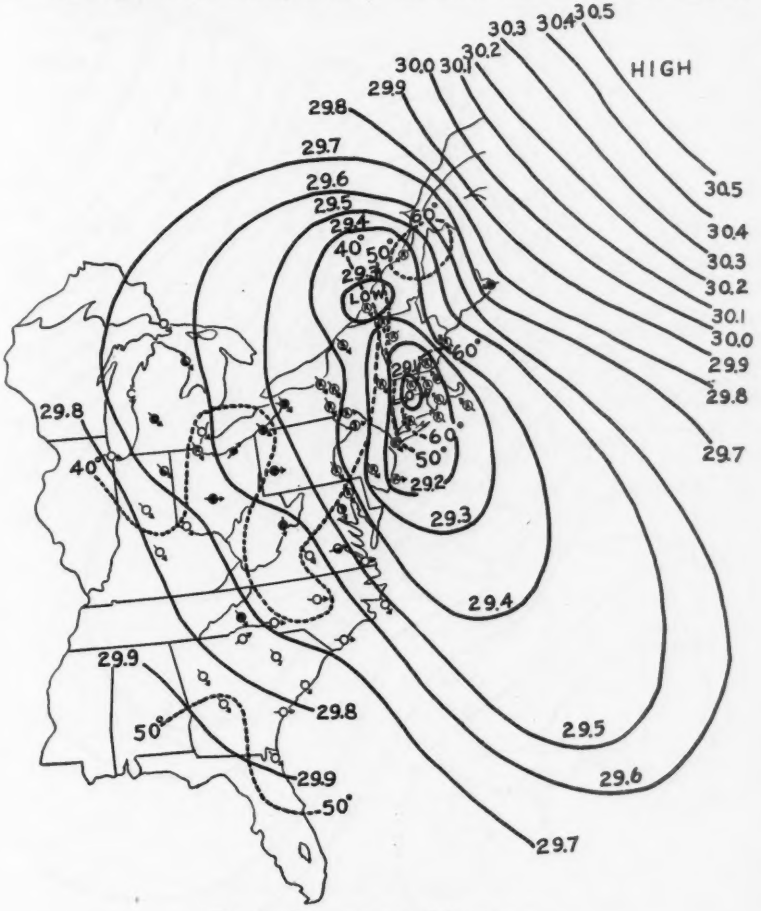

FIG. 4.— NOVEMBER 4, 1927.— 4 A.M.

weather stations. It is interesting to note that although Quebec, Que., had a strong northeast wind, the temperature rose from 42° F. at 8 P.M. to 56° at midnight, and to 62° at 4 A.M., November 4. This warmth continued to the late afternoon of that day and was due to the warm air traveling from the southeastward, some passing down and over the mountains, where much latent heat was given up, and then in a curved path from the northeast up the St. Lawrence Valley. At Northfield there was a somewhat

similar rise, from a temperature of 44° F. at midnight to 59° at 3 A.M., but this warmth was short-lived, for soon after 4 A.M. the cold air again held sway at the surface, the mercury tumbling to 46° at 8 A.M.

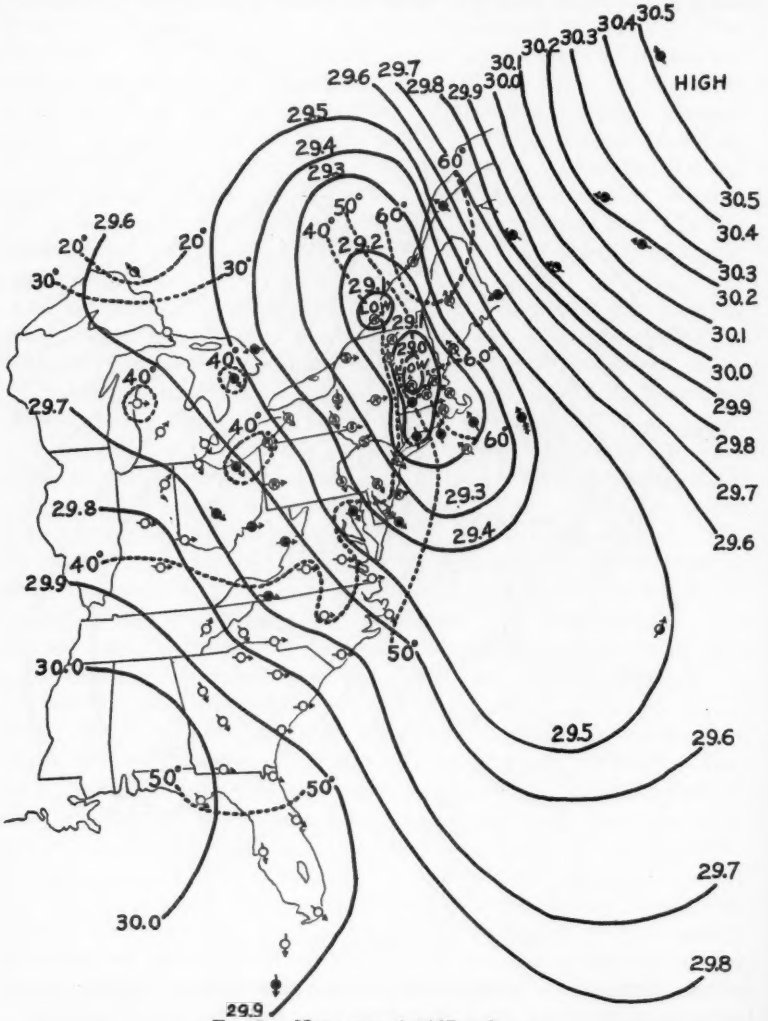

FIG. 5.— NOVEMBER 4, 1927.— 8 A.M.

Figure 5 indicates that at 8 A.M. the two storm centers were still present, as at 4 A.M., but both had increased in intensity. The southern center had moved up the Connecticut Valley to southern Vermont and New Hampshire, Brattleboro, Vt., reporting an unusually low barometer reading

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of 28.97 in. (reduced to sea level). The northern center moved but little and the pressure had fallen to 29.08 in. at Montreal. The cold air that had advanced to the Atlantic Ocean south of New York City by midnight,

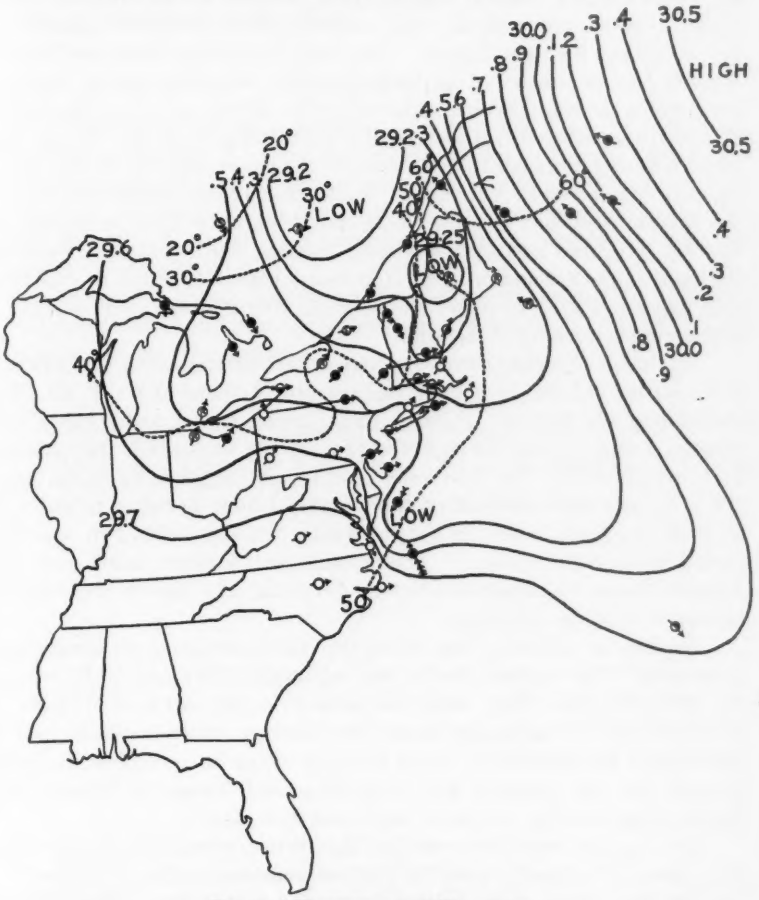

FIG. 6.— NOVEMBER 4, 1927.— 8 P.M.

November 3, had added to its conquest in the following eight hours only a portion of Massachusetts and Connecticut west of the Connecticut River.

The high-pressure area to the northeastward had remained stationary, with slightly increased strength compensating for the loss of air from New England. The two daily, northern hemisphere, weather maps made by Mr. W. P. Day, U. S. Weather Bureau, Washington, D. C., show that this Atlantic high was built in part from dense air relayed southwestward and southward from eastern, southern and southwestern Greenland by four

lows successively from October 29 to November 4. These lows first appeared on the maps, (1) in Central America October 15, with a companion over the Bahamas, October 17; (2) over Hudson Bay October 25; (3) over the Plateau region, western United States, October 25, an offshoot from a low; (4) in the Gulf of Alaska, that was first mapped October 19, approaching the western Aleutian Islands. This fourth low as it passed across North America had its primary center far in the north, with an energetic secondary crossing the continent in middle latitudes. It was this secondary that, as already mentioned, marked on the United States weather maps the western border of the great warm wave of the closing days of October and the first day or two of November. While its southern trough lingered on the Atlantic seaboard this low center moved northward to the mouth of Hudson Bay, then eastward, evidently crossing south central Greenland the night of the 3rd and bringing in its rear a considerable rise in pressure that appears to have increased the stagnant Atlantic high to its 30.72-in. maximum the evening of the 4th.

St. John's, Newfoundland, reported a barometer reading of 30.39 in. at 8 A.M., the 3rd, but by 8 P.M. it had risen to 30.53 and at 8 A.M., the 4th, the reading was 30.58 in. Sydney, Cape Breton Island, had a rising barometer during the 3rd but by 8 A.M., the 4th, the reading was the same as 24 hours previous. The barometer readings on the morning of the 4th, 300 miles east and southeast of Newfoundland, were in the neighborhood of 30.60 in., while farther to the eastward a reading of 30.72 in. was reported by the *S.S. Leviathan*. The pressure had, however, fallen over the Atlantic Ocean southeastward beyond Bermuda, this station reporting a barometer reading of 29.48 in.

During the following four hours the storm continued its northward movement. The southern center was northwest of Concord, N. H., where the barometer read 29 in., while the northern center was west of Quebec. The cold front had advanced around the southern center to Rhode Island and central Massachusetts. Rain was still falling in some New England districts but the amounts were inconsequential, except in Maine. At Eastport the rain did not set in until dusk that day.

By 4 P.M. the southern center had moved to northern New Hampshire, with decreased intensity, while the northern center was still west of Quebec. The last map of this series, 8 P.M. (Fig. 6), shows that the southern center was northwest of Greenville, Me., while the northern center was somewhere in the northwest portion of the Province of Quebec, Doucet having 29.18 in. (sea level pressure). A slight secondary was developing near the coast of New Jersey as the eastward advancement of the cold air over southern New England began to isolate a portion of the warm, humid air mass. Rain had ceased in New England except in Maine, as the cooler, drier air covered that area; the cold front had moved to central Maine. Another secondary developed east of New England and with the low in Maine moved northward, finally disappearing from the map in Arctic America and Green-

land, November 9–11. The Atlantic high was centered near the Azores, November 11. Just two weeks and four weeks after the storm of November 3–4, 1927, similar, though less intense ones struck northern New York and New England and western New York. Record floods occurred in the Genesee River early in December.

Conclusion.

Thus we see that the exceptional rains were due to a rare combination of a great quantity of humid tropical air pushed northward between two flows of polar air, and that the rain was precipitated chiefly where the warm, damp air was forced in large masses over a barrier of mountains backed by a higher barrier of cold air, or where forced to similar heights in a secondary low of small dimensions.

It is worth noting that the great rainstorm of October 3–4, 1869, was of tropical origin and that it was preceded, September 8, 1869, by a hurricane in eastern New England.

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PROCEEDINGS.

December Meeting.

City Club, Boston, Mass.
Wednesday, December 14, 1927.

Vice-President, Robert Spurr Weston, in the chair.

Members of the Affiliated Technical Societies of Boston and the New England Water Works Association: The meeting this afternoon, under the auspices of the New England Water Works Association, is one of the Affiliated Technical Societies of Boston, and I am going to ask the chairman of that organization, Col. L. E. Moore, to say a few words to us.

Remarks by Mr. Lewis E. Moore, Chairman of the Affiliated Technical Societies of Boston.

I just want to say a few words this afternoon about the objects of the Affiliation. I shall not be very long, because our program is rather crowded and I know there are things of greater interest to you than my remarks.

You have all heard what the Affiliation is. It consists of a confederation of thirteen different societies or local sections of national societies, and exists largely to make it easy for engineers in this section to achieve some degree of solidarity. Thirteen separate organizations trying to accomplish anything do not get very far. One organization can perhaps go a long way.

Many of the activities of the Affiliation are not perhaps quite obvious. The meeting rooms, the library, and so forth, are very obvious. The practical impossibility of holding a meeting such as this without some such organization as the Affiliation, I need only to bring to your attention very briefly. We have all the mailing lists together; we can get all the engineers together. Also in matters concerning legislation, when it seems desirable to do something, as it may, for instance, in the case of building laws, we can easily get together. Such questions as the licensing of engineers can be handled easily through the Affiliation, whereas any concerted action from thirteen different organizations would be quite impossible. It is in these ways that the Affiliation is of use. Its work is perhaps not always obvious on the surface. Then of course the Bulletin is valuable in that you get information in it about the activities of the other member societies. This information would not come to you in the ordinary course of events unless you happened to be a member of all of the thirteen, and I do not think anybody is a member of all of them; and you get the information in a convenient and compact form.

One thing that I want to emphasize is that any member of any of the

Affiliated Societies is welcome to all the meetings of all the Affiliated Societies. So that if you see in the Bulletin any meeting which looks interesting to you, do not hesitate to attend it; you will always be welcome.

I think that I have used up all of my time and I shall return the meeting to your chairman. (*Applause.*)

The following papers were presented:

"Pipe-Line Welding from the Oxy-Acetylene Viewpoint," by Le Roy Edwards, Industrial Engineering Department, Air Reduction Sales Company, New York.

"Pipe Welding and Other Recent Developments in Welding," by D. H. Deyoe, Industrial Engineering Department, General Electric Company, Schenectady, N. Y.

"Thermit Pipe Welding," by Robert L. Browne, New York and New England District Sales Manager, Metal and Thermit Corporation, Boston, Mass.

"Replacing Castings by Steel Elements Cut to Shape by Automatic Shape-Cutting Machines," by Dr. A. Krebs, Treasurer, General Welding and Equipment Company, Boston, Mass. Mr. W. M. Mill, Manager, Thomas Smith Company, Worcester, Mass., showed slides illustrating work done by this method.

"The Metallurgy of Welding-Wire," by C. A. McCune, Director of Research, American Chain Company, Bridgeport, Conn.

These papers were discussed by Messrs. E. E. Lochridge, Frank B. Walker, W. R. Conard, C. S. Dresher and L. E. Moore.

(*Adjourned.*)

January Meeting.

City Club, Boston, Mass.
Wednesday, January 11, 1928.

Vice-President Arthur D. Weston in the chair.

The Chairman. Since the last meeting we have lost through death Mr. George A. Carpenter, the President of this Association. I wish that I might be able to express to you just how I feel towards Mr. Carpenter, and how I know that you all have felt. Inasmuch as I have not the ability to do so, Mr. Harrison P. Eddy will say a few words to you about Mr. Carpenter.

Mr. Eddy then read an appreciation of President Carpenter. (See page 1.)

The following papers were read:

"Relining Payson Park Reservoir; Cambridge Water Works," by Lewis M. Hastings, City Engineer, Cambridge, Mass.

Timothy W. Good, Superintendent of Water Works, Cambridge, Mass.,

and Arthur J. White, Vice-President and Manager of the Rust Engineering Company, took part in the discussion.

"Rainfall in New England during the Storm of November 3 and 4, 1927," by X. H. Goodnough, Chief Engineer, Massachusetts Department of Public Health.

"Course of Storm of November 3 and 4, 1927," by J. Henry Weber, Clark University, Worcester, Mass.

This paper was discussed by H. P. Kinnison, District Engineer, United States Geological Survey, Custom House, Boston.

Owing to the lateness of the hour it was impractical to throw the meeting open for a general discussion, but the following gentlemen were introduced by the Chairman:

Professor Charles F. Brooks, Clark University, Worcester, Mass.; George H. Loveland, Meteorologist, Weather Bureau, Boston.; Mr. Shaw of Clark University.

(*Adjourned.*)

DANIEL KENNEDY — A Memoir.

Daniel Kennedy, President of The Kennedy Valve Manufacturing Company, died at Hot Springs, Ark., on January 14, after a short illness.

Mr. Kennedy was in his eightieth year, came to America from Ireland as a youth of seventeen, and was a self-made man in every sense of the word. In the trade, as well as in his home city, he was highly esteemed and a leading industrial figure. He had the distinction of originating and for half a century guiding the destinies of a firm that is today recognized internationally as a pioneer and leading builder in the valve, fire hydrant and pipe-fittings field.

Mr. Kennedy's primary interests were in his family and in his business, to both of which he was conscientiously devoted. In private life he was of a retiring disposition and had an abundance of sterling qualities. His philanthropies were innumerable, but were carried out anonymously and with the reserve that was characteristic of the man. With his hundreds of employees, he enjoyed that popularity which is invariably courted by men in his position, but is often lacking. He knew many of his men personally, called them by their first names, and lived to see many of the sons and even grandsons of old-time employees grow up in the business.

Besides his widow, Mr. Kennedy is survived by three sons, Matthew E., J. C. and Clarence H., Treasurer and General Manager, Works Manager and General Sales Manager, respectively, of The Kennedy Valve Mfg. Co.; and by three daughters, Mrs. John C. Judge of Brooklyn, N. Y., Mrs. Alexander H. MacCreery of Tulsa, Okla., and Miss Kathleen Kennedy of Elmira.